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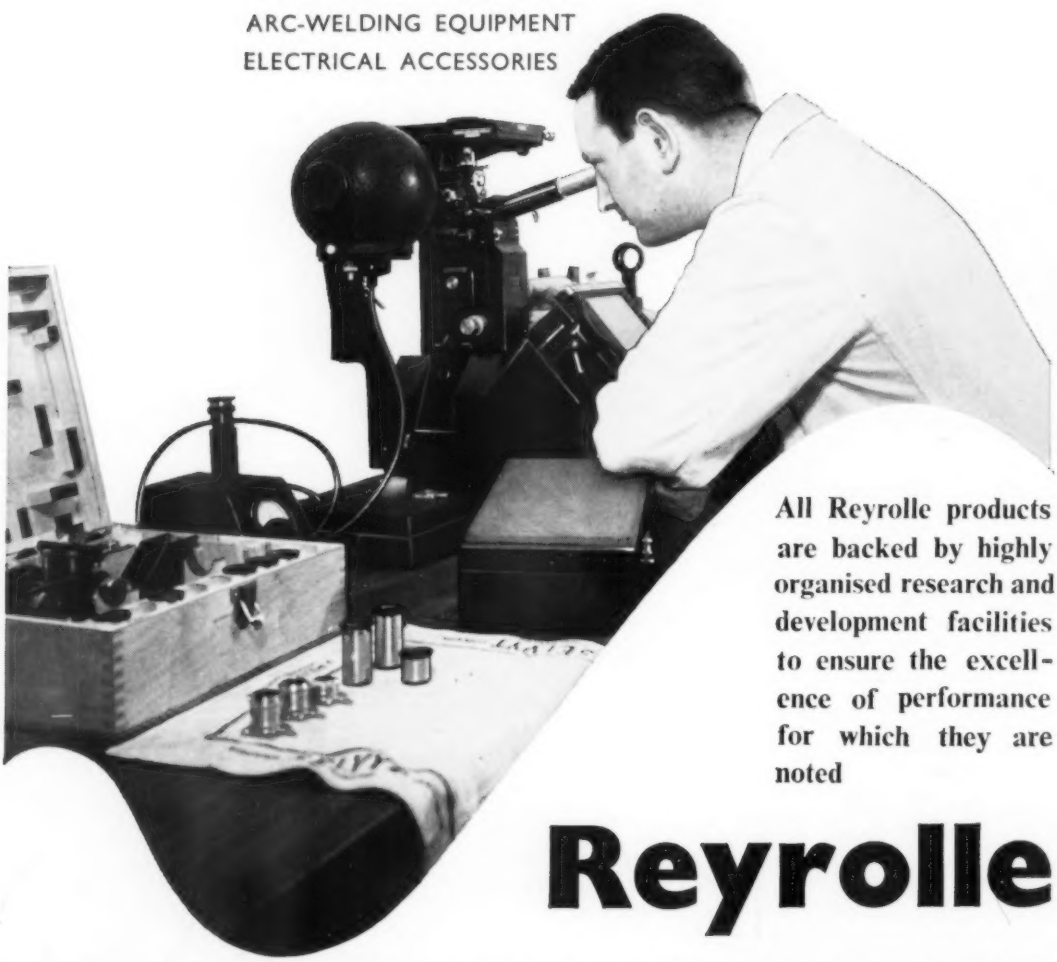

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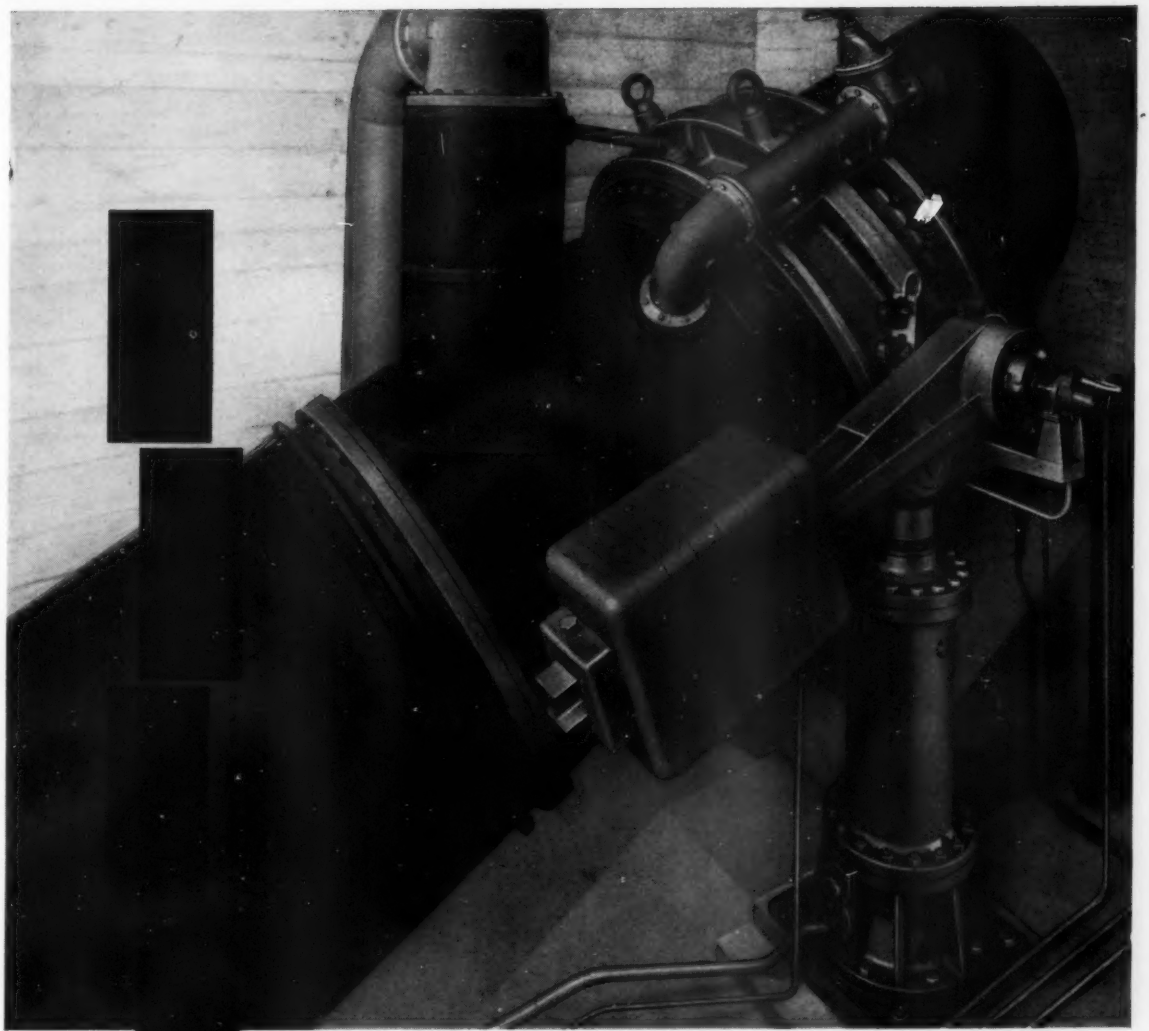

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322

This is the stone
that makes
the tower
stand or fall.
In a Power Station
it is the **Shut-off Valves**
that provide for the safety
of the entire plant
and thereby
make it stand or fall

DE ROLL

Shut-off Valves

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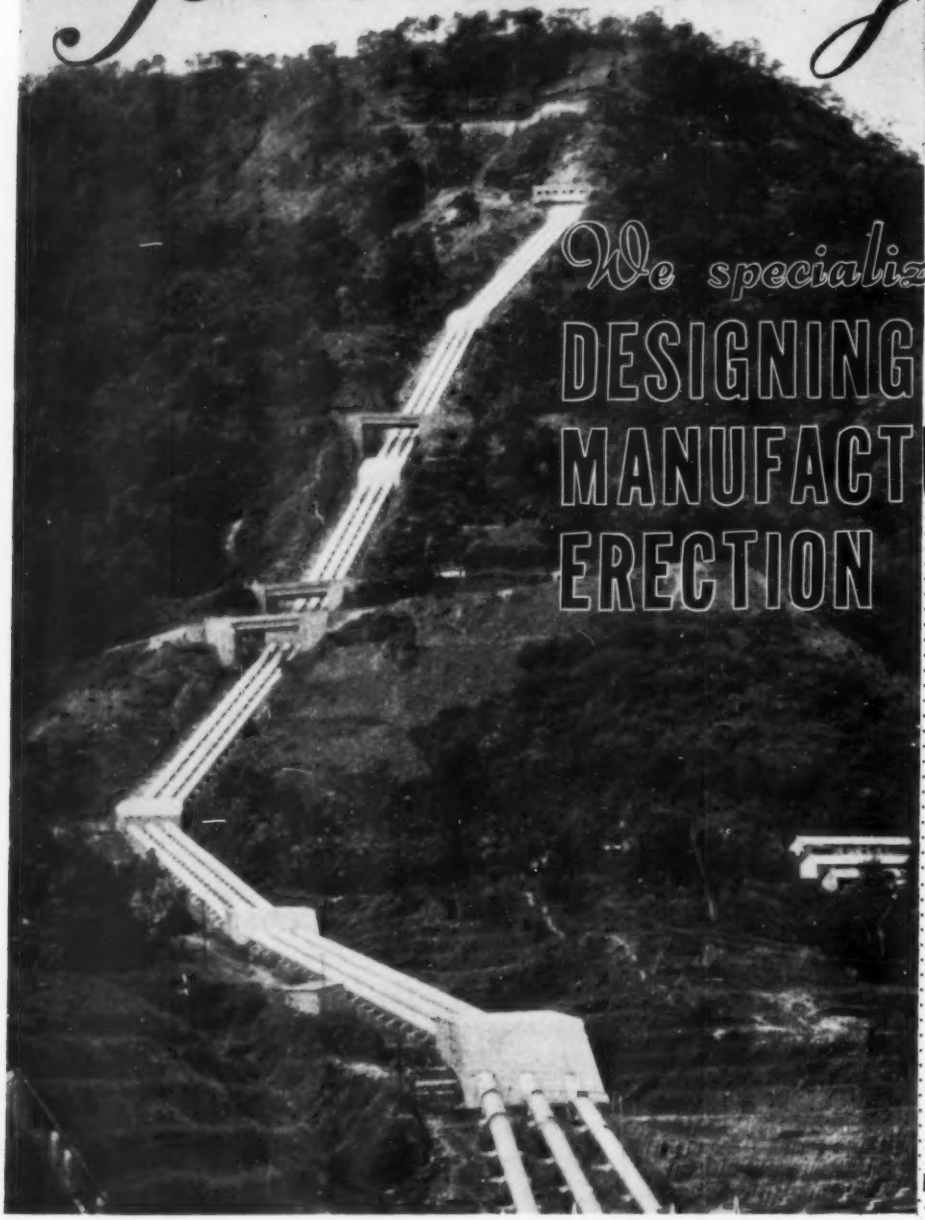

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Bell builds:
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Some projects with Bell Equipment:
Francis Turbines - Guyabo (El Salvador) head 56 m, 24'800 HP - Bärenburg (Switzerland) head 340 m, 85'000 HP (Supply together with Charmilles)
Pelton Turbines - Göschenen (Switzerland) head 698 m, 64'000 HP - Sedrun (Switzerland) head 588 m, 70'000 HP
Kaplan Turbines - Wildegg Brugg (Switzerland) head 15,3 m 34'000 HP - Petäjäskoski (Finnland) head 19 m, 67'600 HP

Bell Engineering Works Ltd.
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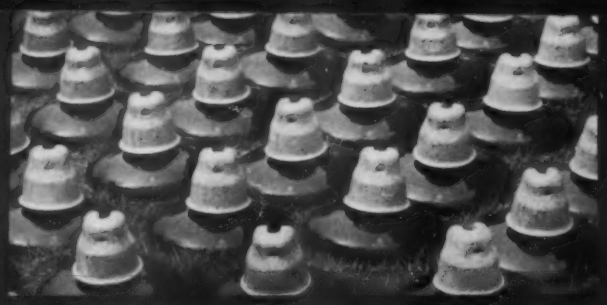

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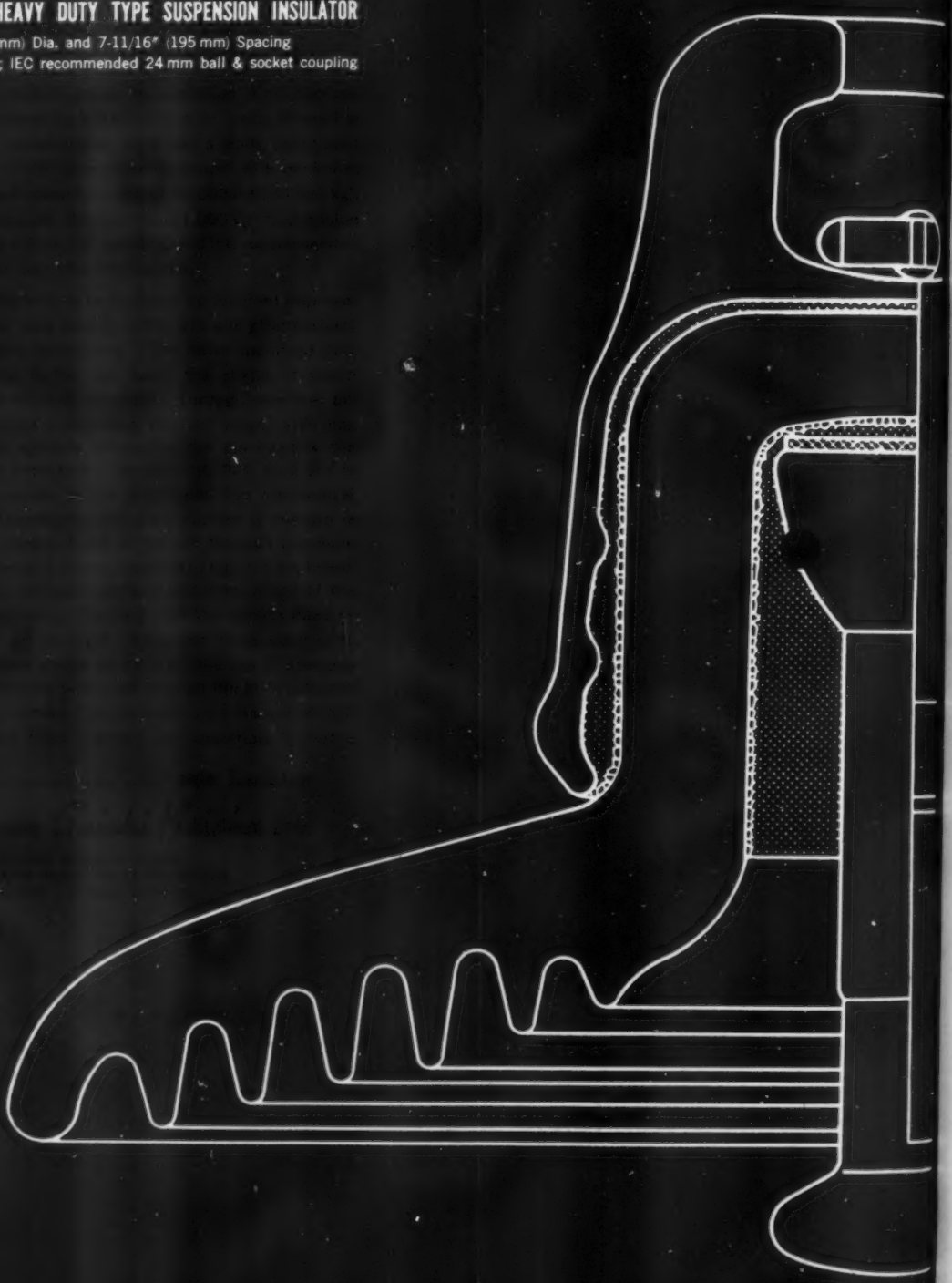
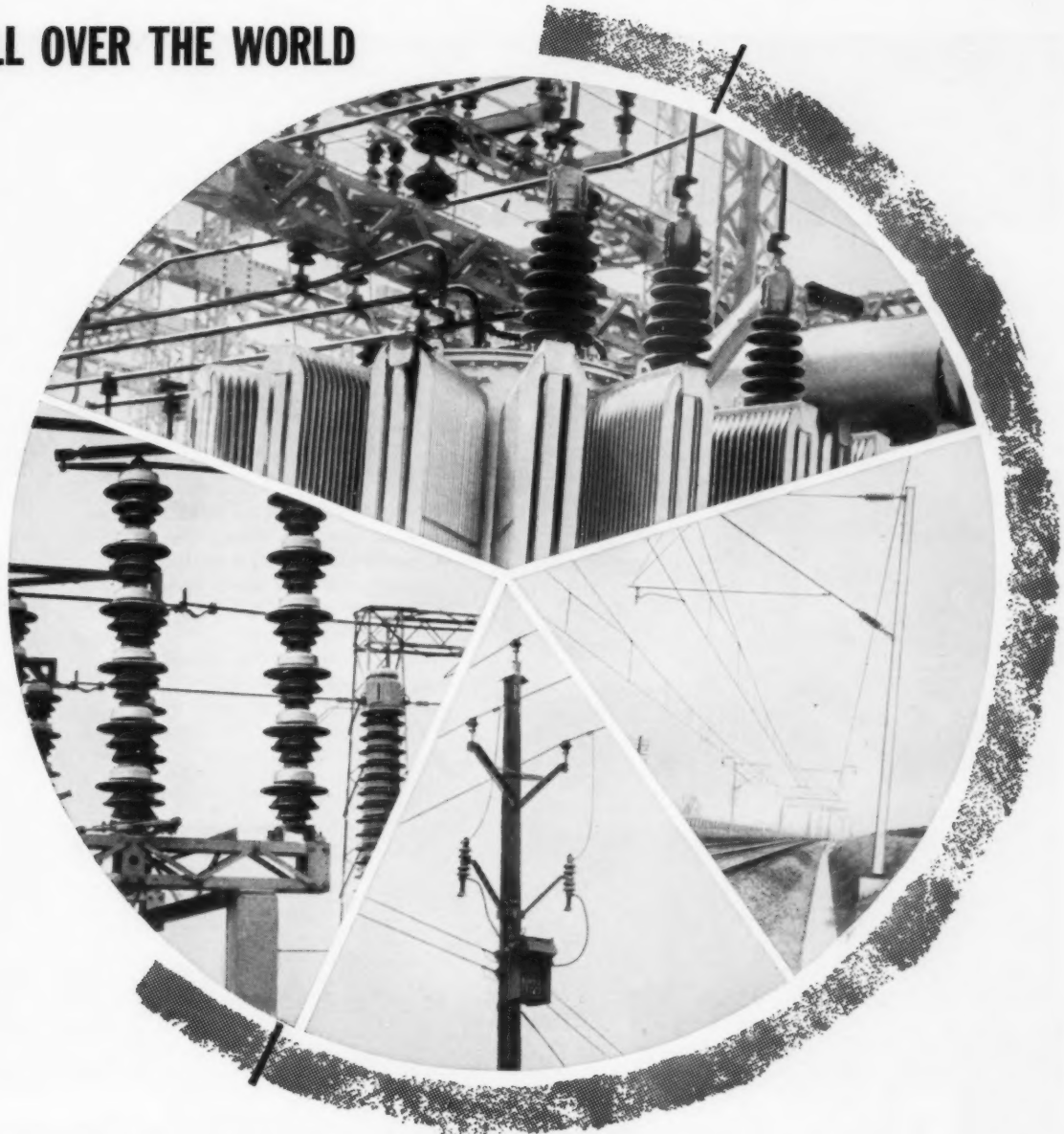


ALL OVER THE WORLD



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lock gates,
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bottom outlets and
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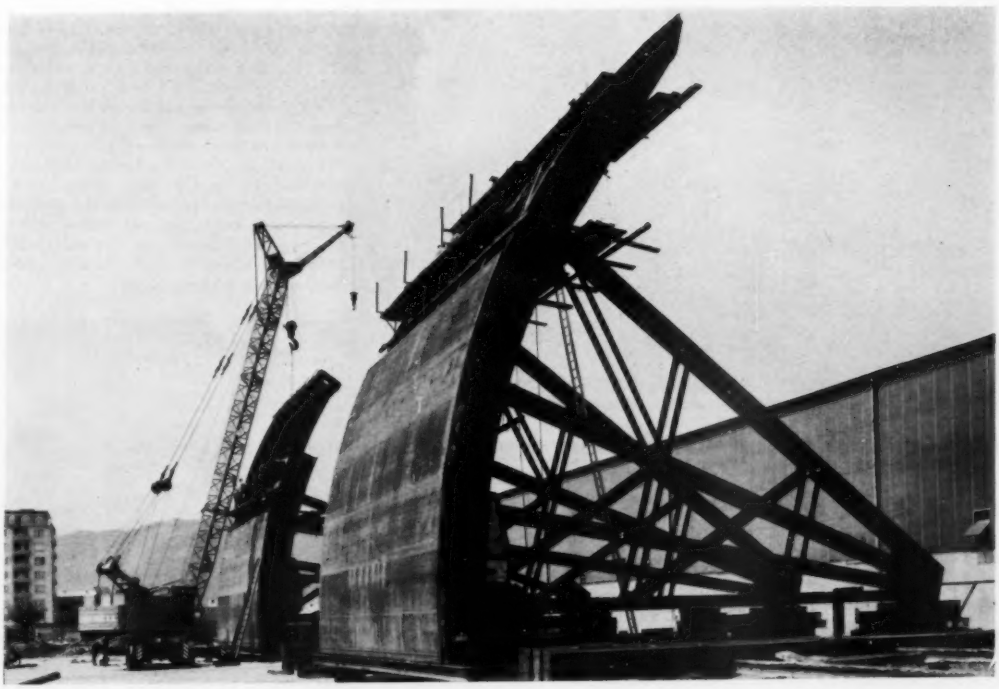

Spillway Radial Gates for Bhumiphol Dam, Thailand; height 17.4 m, width 11 m, weight 130 t. each.

WAAGNER-BIRÓ

WIEN AKTIENGESELLSCHAFT **GRAZ**

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Welder Svensson is going places

He certainly is. Trained at Svenska Metallverken's Welding Institute, he has been busy at atomic reactor projects in Belgium and the Netherlands, as well as in Sweden itself. Aluminium is in many ways an excellent material for nuclear applications, but... considerable skill is required in welding it. Here Svenska Metallverken's long experience of working aluminium has proved invaluable. Even before the first World War, Svenska Metallverken was welding aluminium. It was first in Sweden, too, to use the inert-gas shielded arc process. And Welder Svensson is not exceptional — what is exceptional is the number of Metallverken-trained welders who are qualified for nuclear work.

POWER LINE BUILDERS BENEFIT TOO

Most of the machines at Svenska Metallverken's Feral Cable department have been designed specifically for the metals in question — in this case aluminium. Here automatic devices help production and offset human failings. Coils of wire rod are welded together before drawing. Large wirebars mean longer rod coils and fewer welds — and even before being coiled, an electronic device has detected any defects in the rod. Then again, there is an automatic device for stopping the machines as soon as a predetermined length of wire has been spooled into the reels of the standing machines — where it finally becomes Feral Cable, reliable Swedish ACSR.

Push-button operated continuous rod-mill at Svenska Metallverken's Feral Cable Department.

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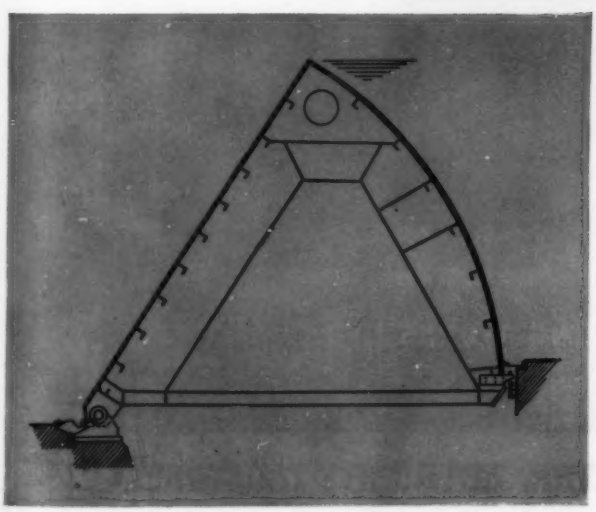

HYDRAULIC STRUCTURES

Sector weir of 50 m clear width and 4.55 m water head in the River Elbe at Geesthacht near Hamburg. Illustration shows the gate in course of erection. Sector weirs are hydraulically operated submersible gates moved by regulation of the water enclosed in the sector chamber. As opposed to drum gates, they are particularly appropriate for weir plants in rivers where comparatively slight variation in the water level occurs.

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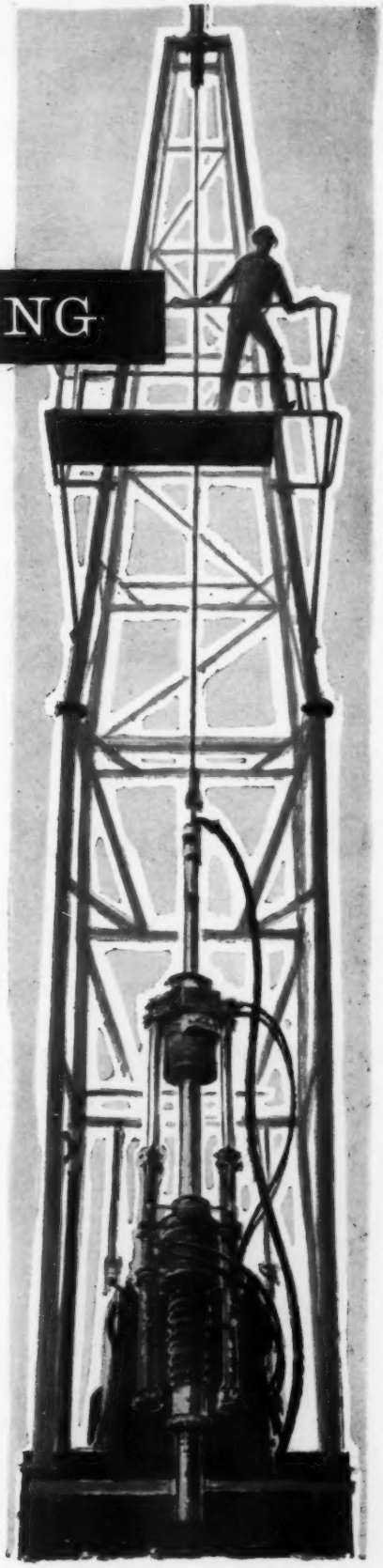
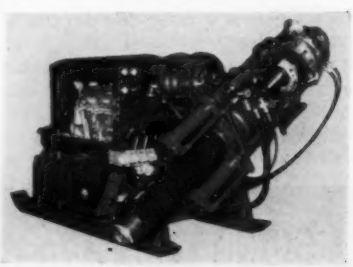
We are at your service with skilled drillers, and equipment to undertake your drilling programme. Or alternatively to supply British manufactured machines and equipment for air or water flush drilling.



Drills, derricks, pumps and equipment. Portable and flexible over a wide range of bore hole depths and sizes.



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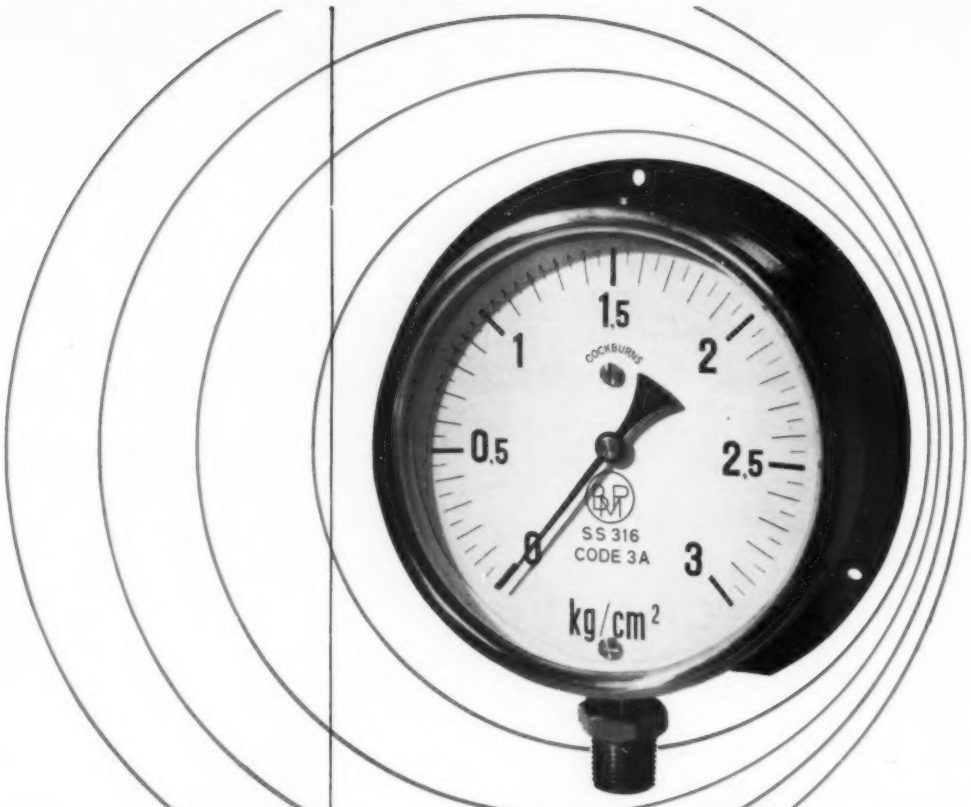

Compound pressure gauges

with zero adjustment

These Bourdon-tube gauges, now being supplied by Cockburns, are exceptionally accurate, robust, reliable and keenly priced. Their design has been proved by extensive use in chemical, petroleum, refrigeration and marine industries throughout the world.

The preliminary-pressure and fluctuation shock inaccuracies common to gauges with needle-stops are completely obviated in the compound design. The zero adjustment ensures complete accuracy over the whole scale, at all times, without recalibration.

Standard gauges are available for all pressures, graduated in lbs./in.^{2} or kg./cm^2. A super quality gauge with heavy duty rotary movement designed in association with leading Oil Engineers is also available. Gauges with special corrosion or wear-resistant internals can be supplied.

Other units included in the range of Cockburns Measuring and Controlling Instruments are:-

— DIAL THERMOMETERS
mercury in steel, vertical and angled models.

AUTOMATIC SAMPLING UNITS
for regular draw-off of liquid samples.

TEMPERATURE INDICATING CONTROLLERS
for oil tank heating systems.

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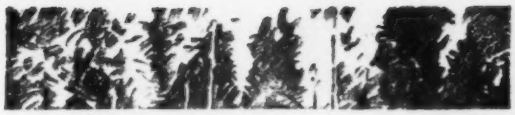
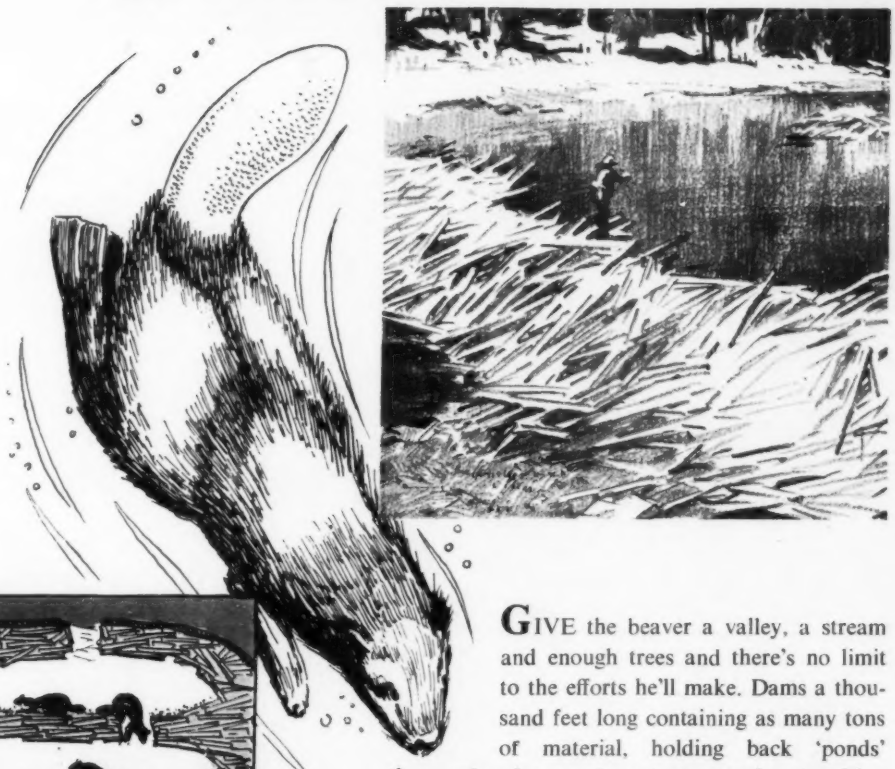
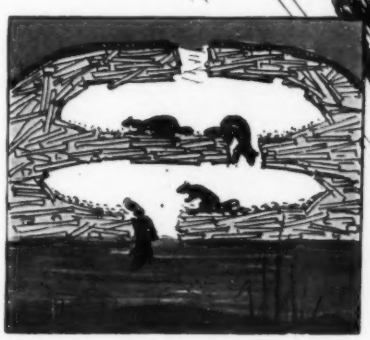


ACHIEVEMENT IN THE WILDERNESS





Cemented with frozen mud, the beaver's lodge shelters him from the elements and his many enemies. The lower chamber, entered from underwater, is his 'dining room,' while above it, the sleeping space is lined with cedarwood shavings or peeled twigs.

GIVE the beaver a valley, a stream and enough trees and there's no limit to the efforts he'll make. Dams a thousand feet long containing as many tons of material, holding back 'ponds' thousands of acres in extent—canals, stretching for hundreds of yards to a particular stand of timber—two-storey 'houses' sometimes forty feet in diameter—a strange and wonderful 'civilisation' flourishing where once the forest stood unchallenged.

On an infinitely greater scale but with the same inexhaustible energy and aptitude for the job we are creating the mechanism of modern life in places which for centuries have withstood the encroachment of man. Like the beaver, we are eager to build —and the wilderness is a challenge to be met and conquered.

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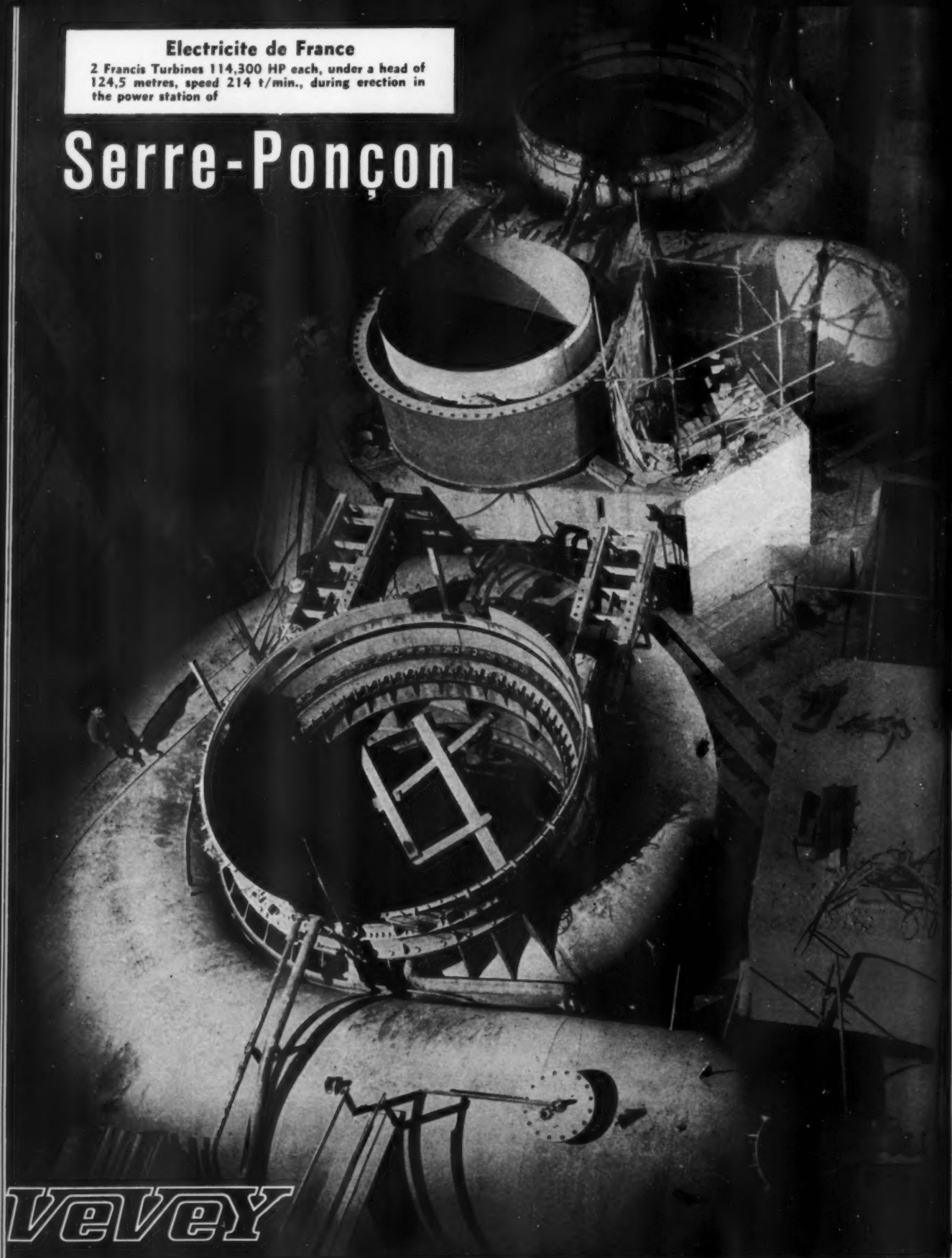
WHARF WORKS PETERBOROUGH

Electricite de France

2 Francis Turbines 114,300 HP each, under a head of 124,5 metres, speed 214 t/min., during erection in the power station of

Serre-Ponçon



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in collaboration with our French licensee:
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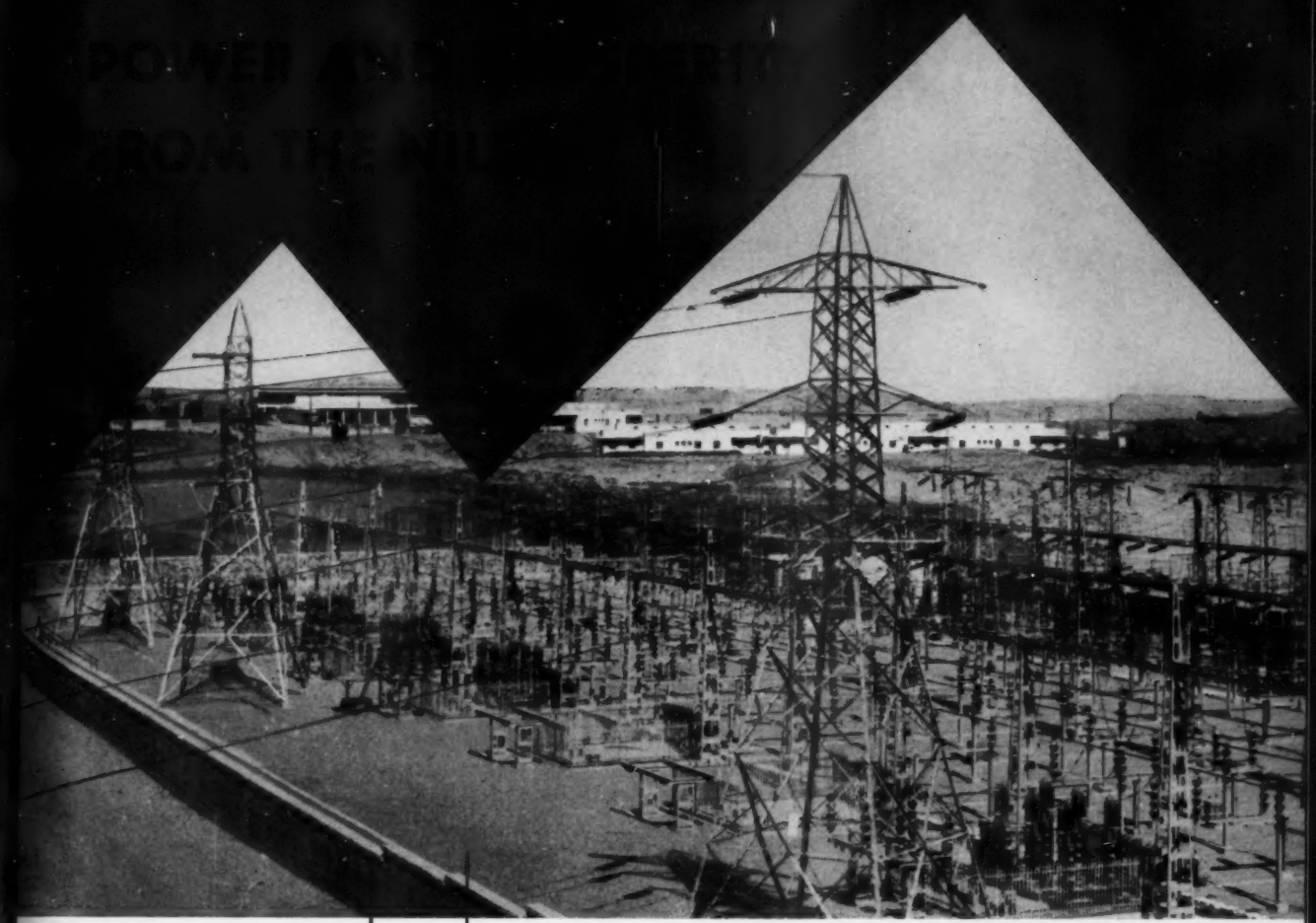

The Nile, the life blood of Egypt, is now harnessed at Aswan to provide power for the needs of the nation.

In addition to supplying two 49.5 MVA generators and all power transformers for this huge project ASEA has also furnished all switchgear, auxiliary apparatus, cables and steel structures for the 132 kV switching station.

For complete
power installations —

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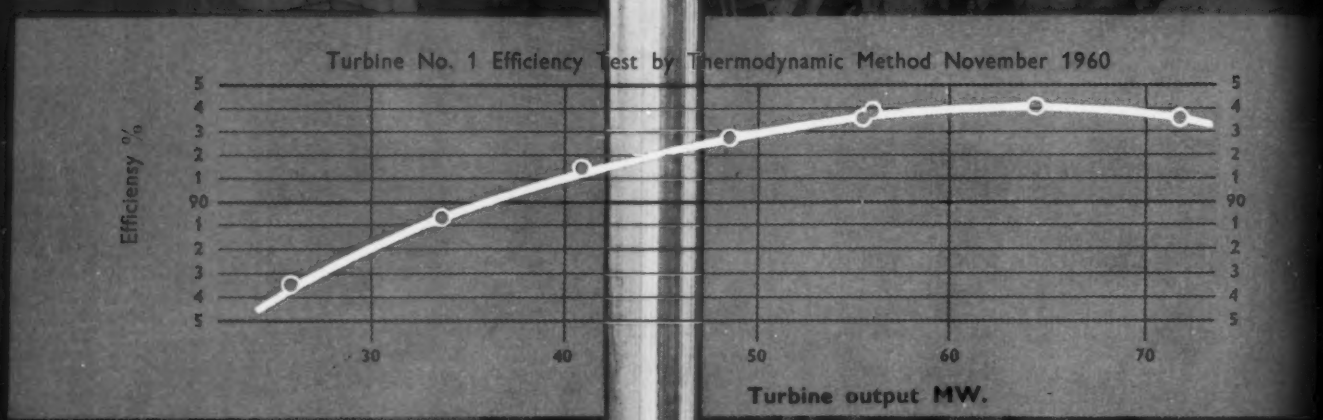
Turbine No. 1 Efficiency Test by Thermodynamic Method November 1960
Efficiency %
5 4 3 2 1 90 1 2 3 4 5
30 40 50 60 70
Turbine output MW.

Runner and shaft for Upper Vinstra Power Plant,
rated output 92,000 H.P., 428 rev./min., mean net head 320 metres.
Kvaerner Brug has delivered Francis turbines for
heads up to 543 metres.

A/S KVÆRNER BRUG
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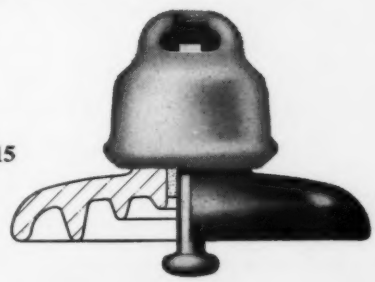
BY DOULTON

Backed by a century and a half of ceramic manufacture, a first class research laboratory, a modern factory, a highly trained technical staff and the latest test equipment, Doultons offer an unrivalled service to the electrical engineering world.

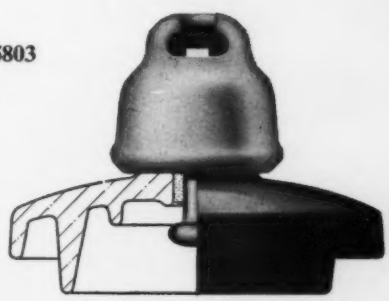
Doulton Insulators are made for standard voltages spanning a range of 400 to 400,000 volts. Many hundreds of thousands are in use to-day over the world's surface.

Three typical designs of high voltage insulators in general use are shown below.

33 kV Pin Insulator, Type BC. 28
Complying with B.S. 137/1960
Minimum Failing Load 2400 lb.



Disc Insulator, Type P.42B/8/5515
Complying with B.S. 137/1960
Minimum Failing Load 42000 lb.



Disc Insulator, Type F.42B/6¾/5803
Complying with B.S. 137/1960
Minimum Failing Load 42000 lb.

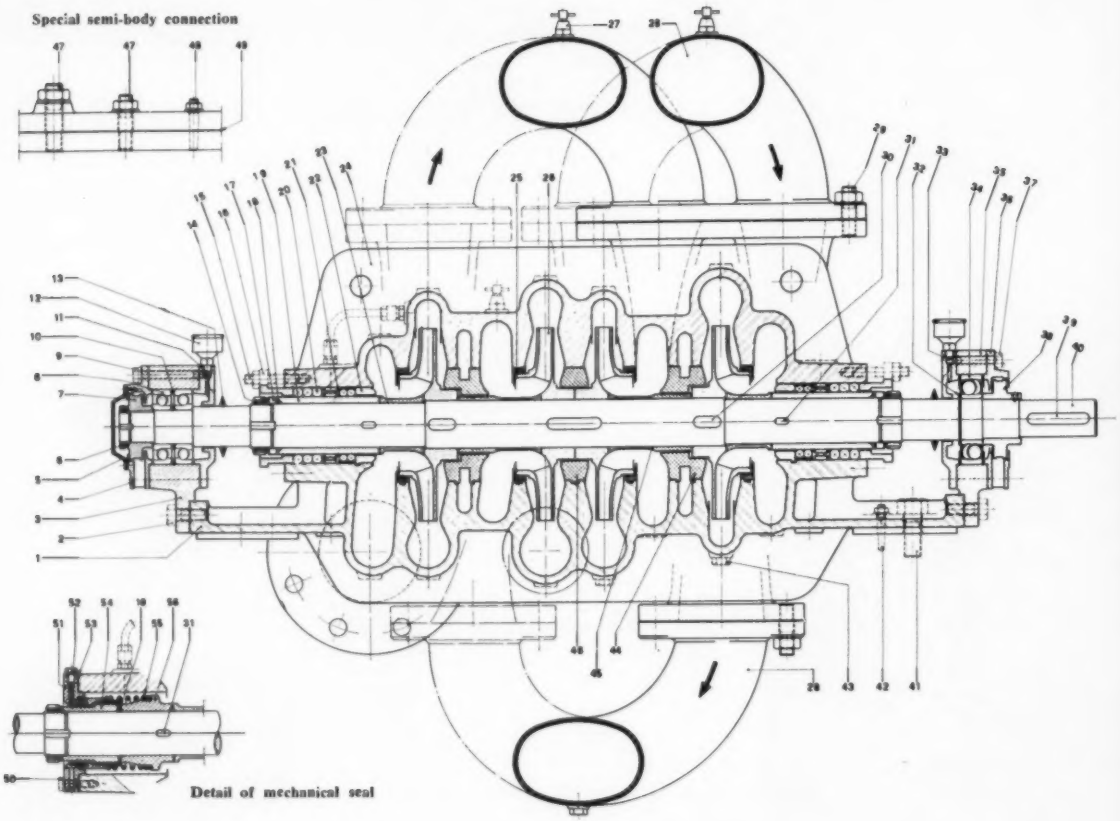
Write to Publicity Department for latest literature

DOULTON INDUSTRIAL PORCELAINS LIMITED

ROYAL DOULTON POTTERIES, WILNECOTE, TAMWORTH, STAFFS.

PD Pump

For water works, storage plants, industrial works, pumping plants.



PD pumps are of the horizontal shaft, single-suction, multi-stage, centrifugal type. Heavy built, these pumps are highly efficient and have every mechanical feature to assure long trouble-free service.

The body of the pump is split in two halves along the horizontal centerline; therefore, it can be easily inspected and quickly dismantled without removing the pump and disturbing the suction and discharge pipe connections. The impellers are in series and opposed in sets, so as to balance the hydraulic pressures. Axial loads on the bearings are thus eliminated, resulting in a more reliable and trouble-free operation of the pump.

The shaft is of high-strength steel and it is lined with protective sleeves where facing the wearing faces of the stuffing boxes with adjustable stuffing glands. Deep boxes accommodate large packing rings. Suitable connections to the sealing supply line are also provided.

Bearing housings of the outboard type, are provided with grease-lubricated heavy duty ball or roller bearings and thrust bearings, for residual or accidental thrusts.

Photo on the left: 2 pumps, type PD 250/300/2, driven by 300 HP NU 2500/4 induction motors, total capacity 24,000 litres (5,280 gallons) per minute, 80-metre (262 ft.) head; 2 pumps, type PD 225/250/2, driven by 200 HP NU 2000/4 induction motors, total capacity 18,000 litres (3,960 gallons) per minute, 80-metre (262 ft.) head. Universal Exhibition Board, Rome.

Please ask for catalogues, price lists, estimates. Our experts are entirely at your service.

Industrie Elettromeccaniche Arzignano - Vicenza - Italy

PELLIZZARI

1961

- a Record Year for KMW Turbines

In 1961 not less than 17 KMW turbines, with a total output of about 900,000 h.p., will be put into service at 11 power stations in different countries.
The picture shows the runner for the Francis turbine for Stalon power station in Sweden. Output 150,000 h.p.

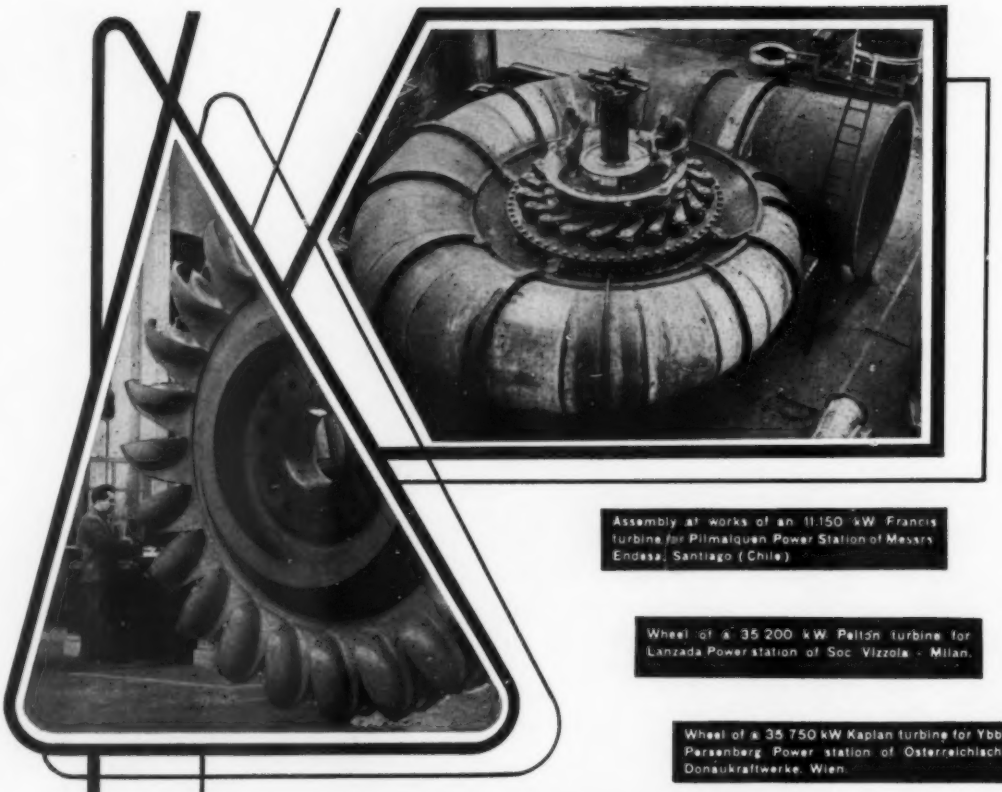
AB KARLSTADS MEKANISKA WERKSTAD

KARLSTAD - SWEDEN

Representatives in Canada: A. Johnson & Co. Ltd., P.O. Box 56, Montreal 16

KMW

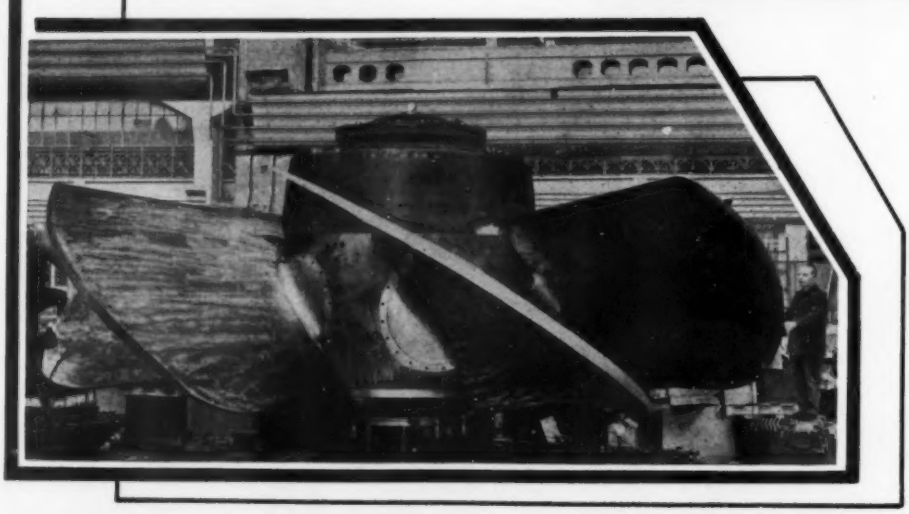
Complete hydro-electric plants



Assembly at works of an 11.150 kW Francis turbine for Pilmalquen Power Station of Messrs Endesa, Santiago (Chile)

Wheel of a 35.200 kW Pelton turbine for Lanzada Power station of Soc. Vizzola - Milan.

Wheel of a 35.750 kW Kaplan turbine for Ybbs Persenberg Power station of Osterreichische Donaukraftwerke, Wien.



ANSALDO-SAN GIORGIO
GENOVA

At Ontario's Red Rock Falls Generating Station on the Mississagi River, Woodward's first production Electric-Hydraulic Waterwheel Governor has been installed. Woodward's twin-type Electric-Hydraulic Cabinet Actuator controls two Dominion Engineering Works Turbines, each rated at 26,500 h.p.

DEBUT
at Red Rock Falls

Woodward introduces new Electric-Hydraulic Waterwheel Governor

For traditional excellence of design, quality of workmanship, precision performance, reliability and service life, Woodward Mechanical-Hydraulic Governors have long been the standard of the world. To these qualities are now added the simplicity and versatility of electric speed sensing with Woodward's new Electric-Hydraulic Cabinet Actuator. Such mechanical devices as the ballhead assembly and temporary droop dashpot are supplanted by static electrical components that offer advantages for certain plants — (1) continuous control signals can be used with particular benefit on fringe control, (2) greater flexibility in arrangement of equipment is possible because electrical controls can be remotely located from the distributor valve assembly, and (3) operating and maintenance personnel are already familiar with similar electrical equipment in other plant functions.

For the finest in prime mover control, always specify Woodward waterwheel governing equipment — either electric-hydraulic or mechanical-hydraulic.

"Worlds oldest and largest manufacturer of hydraulic governors exclusively"

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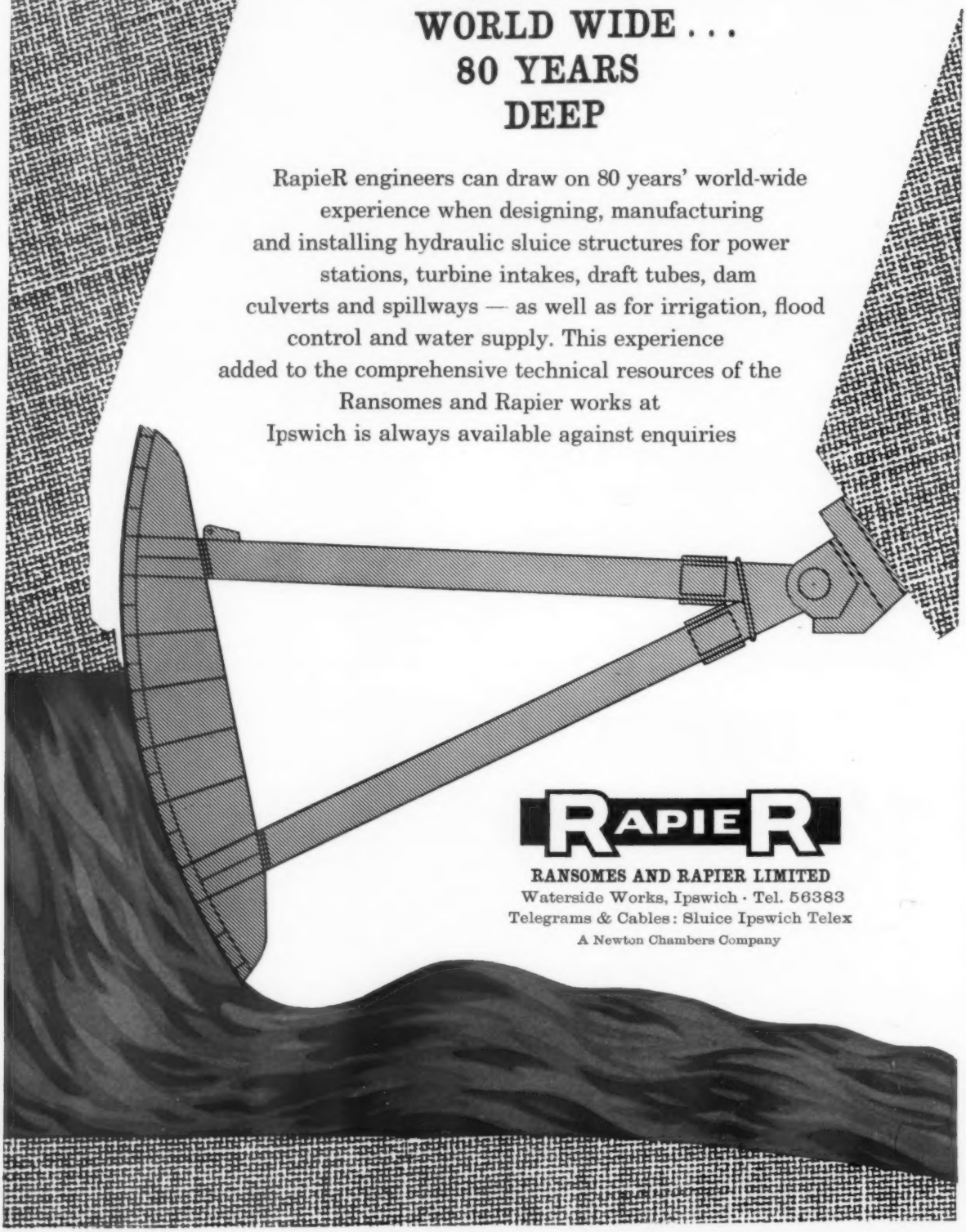

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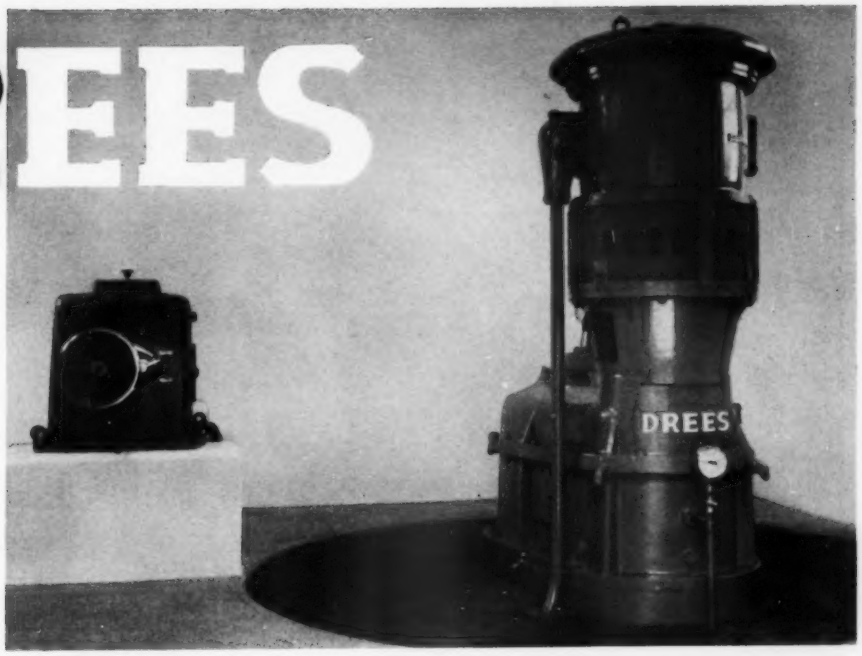

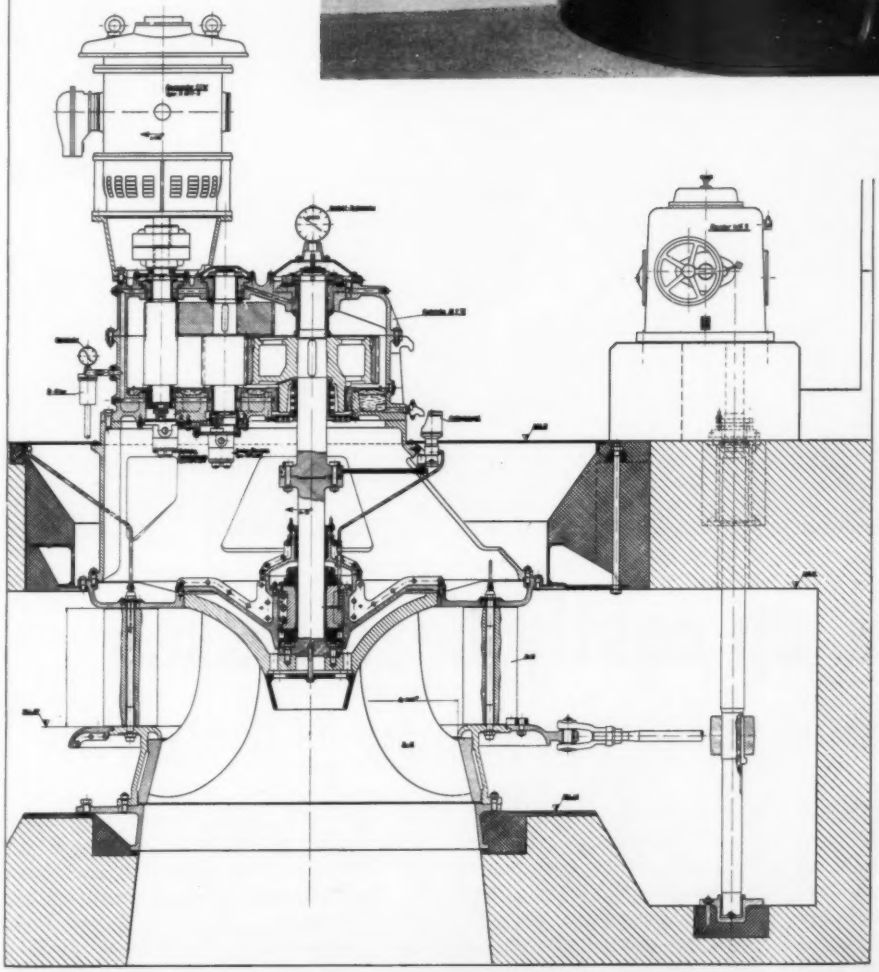

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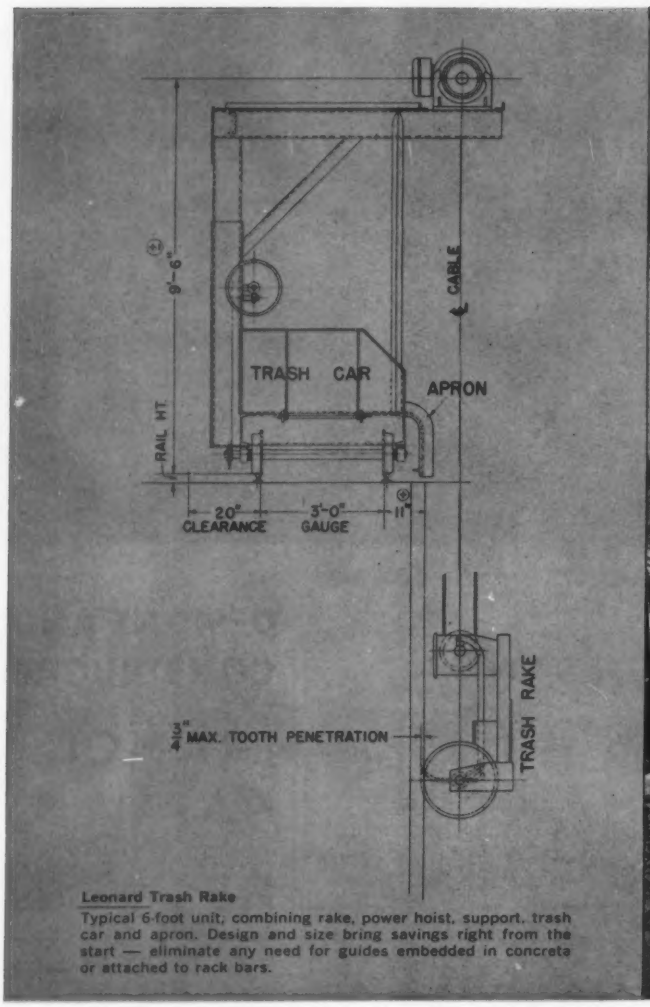

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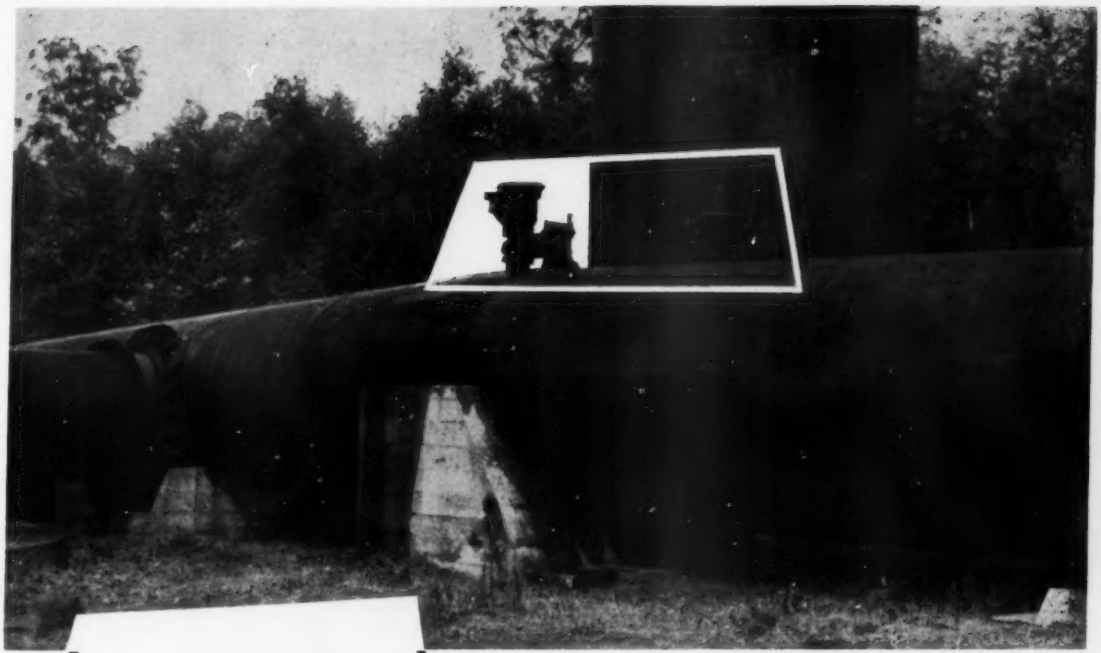

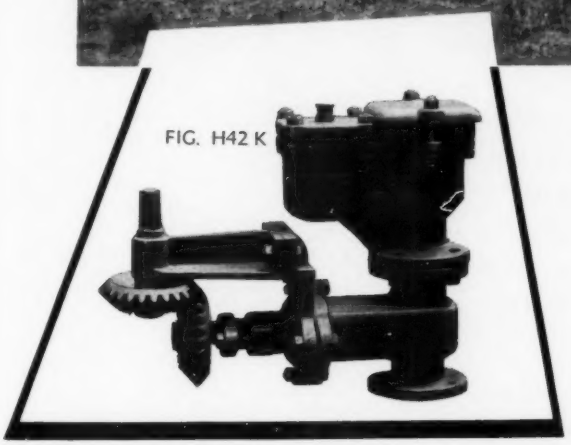

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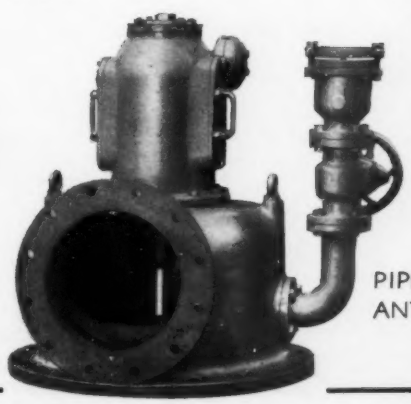

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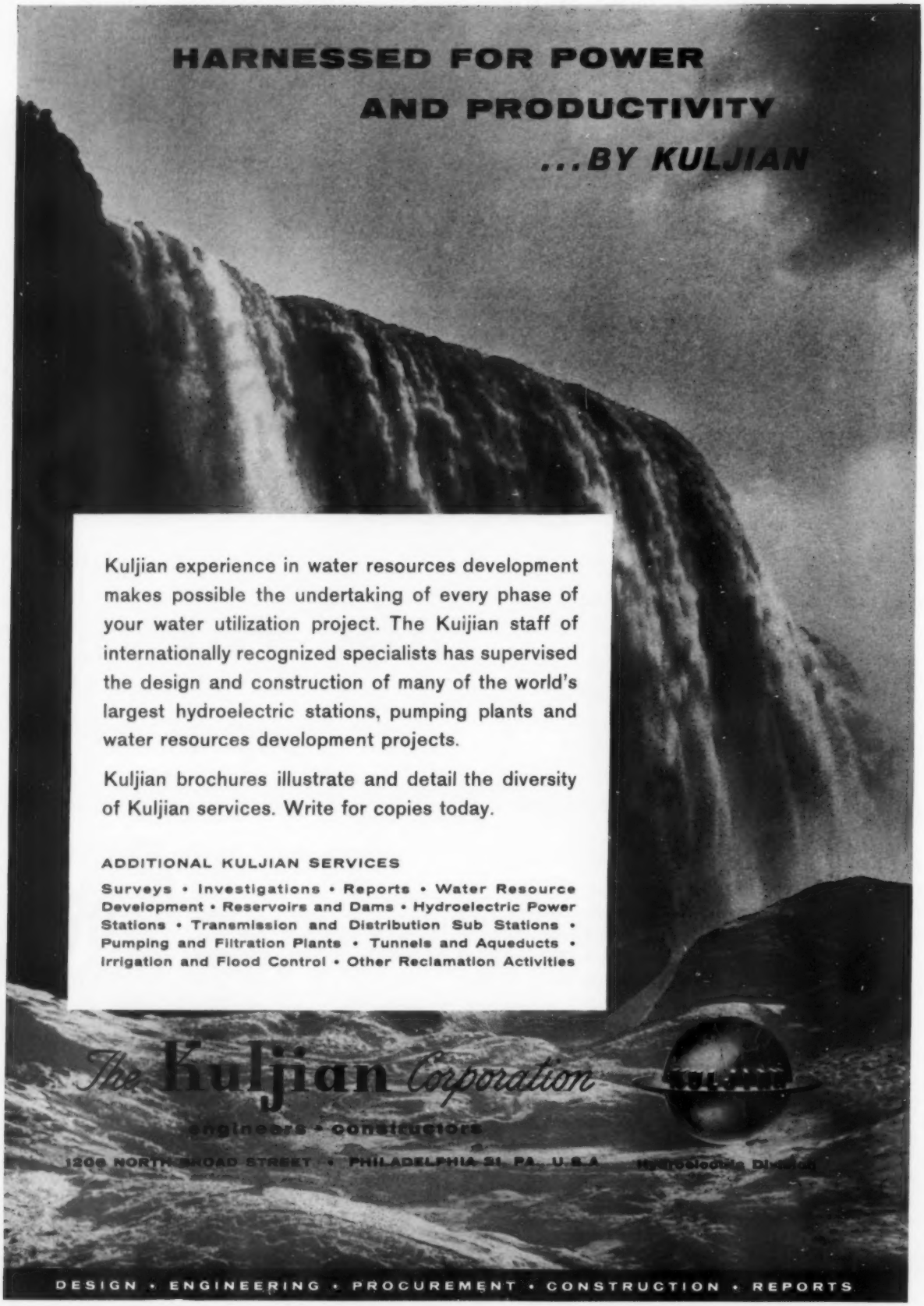
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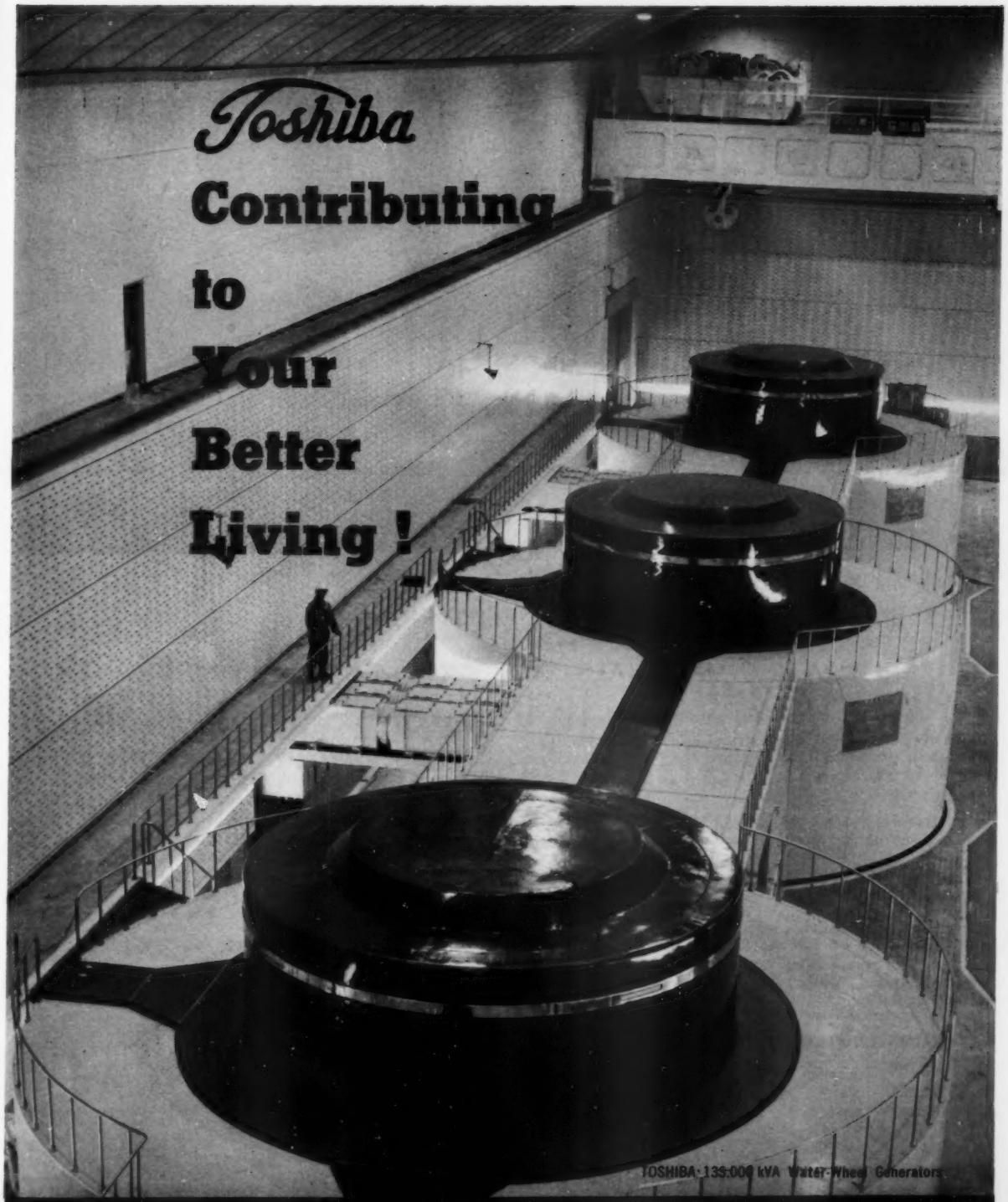

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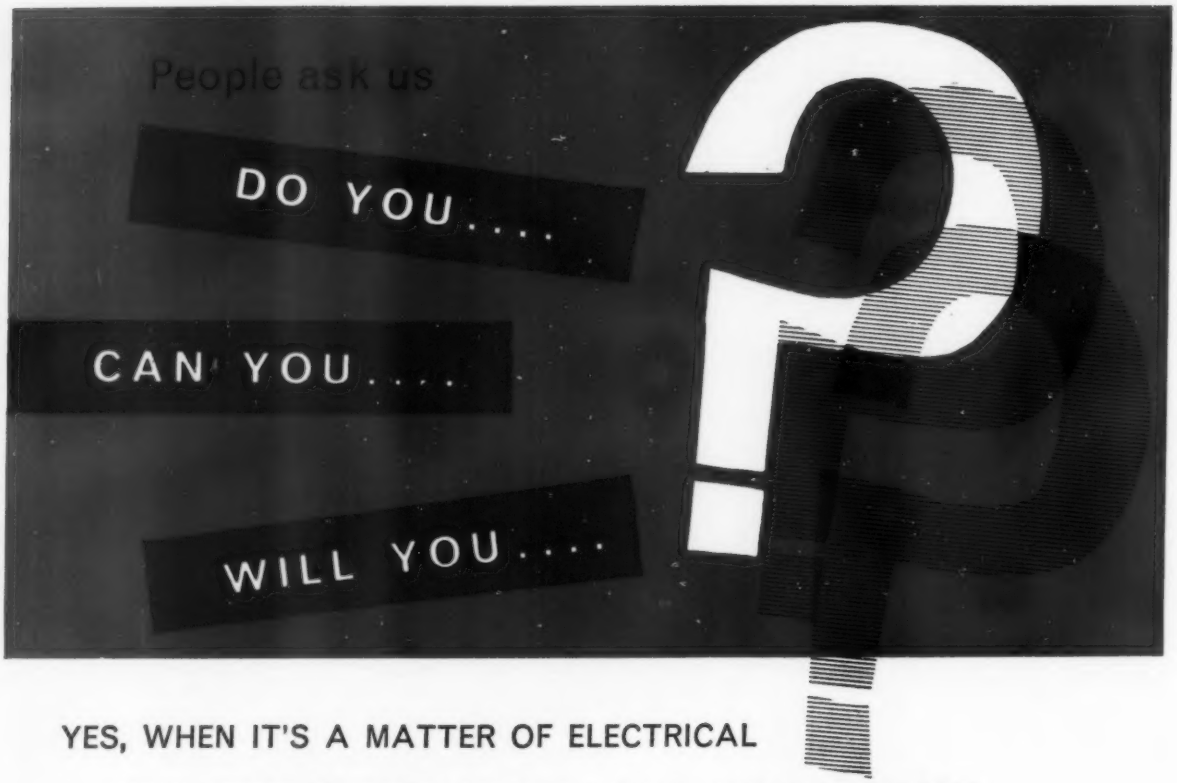

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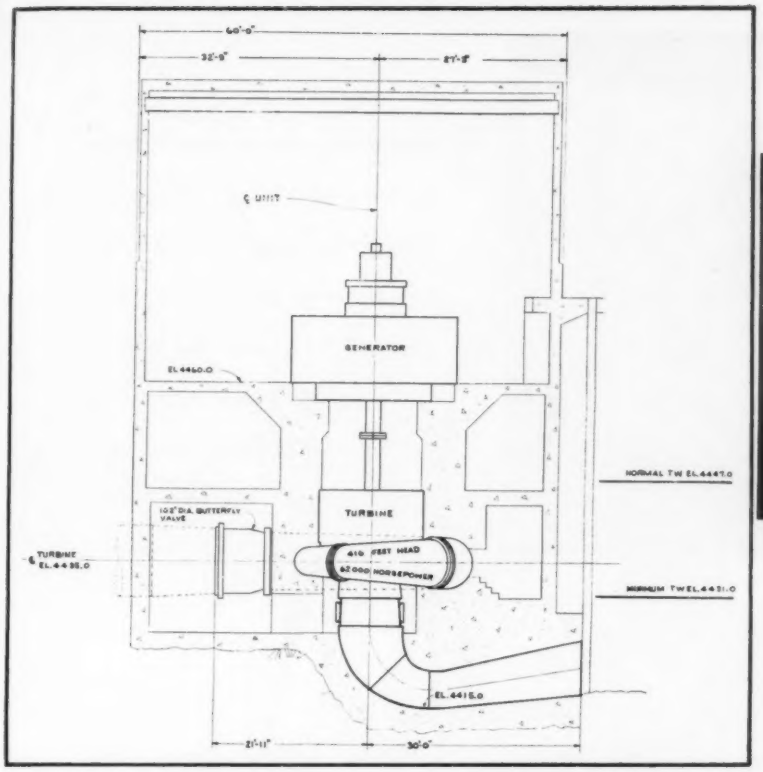

Joining the steel plate scroll casing to the stay ring during factory assembly of the Union Valley turbine.

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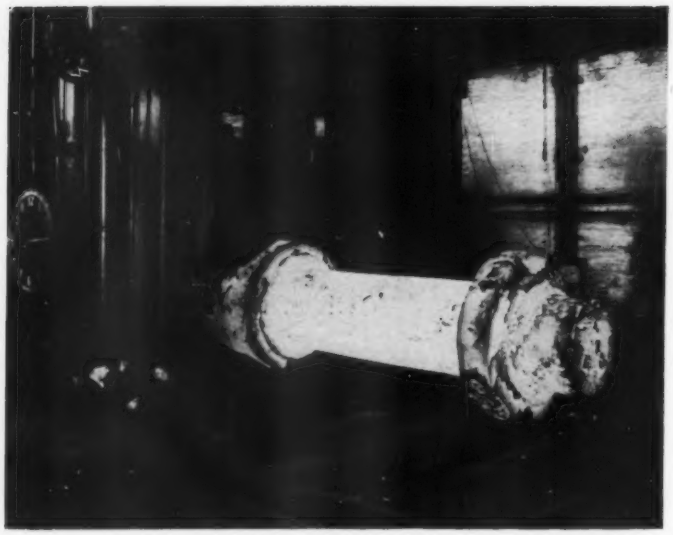

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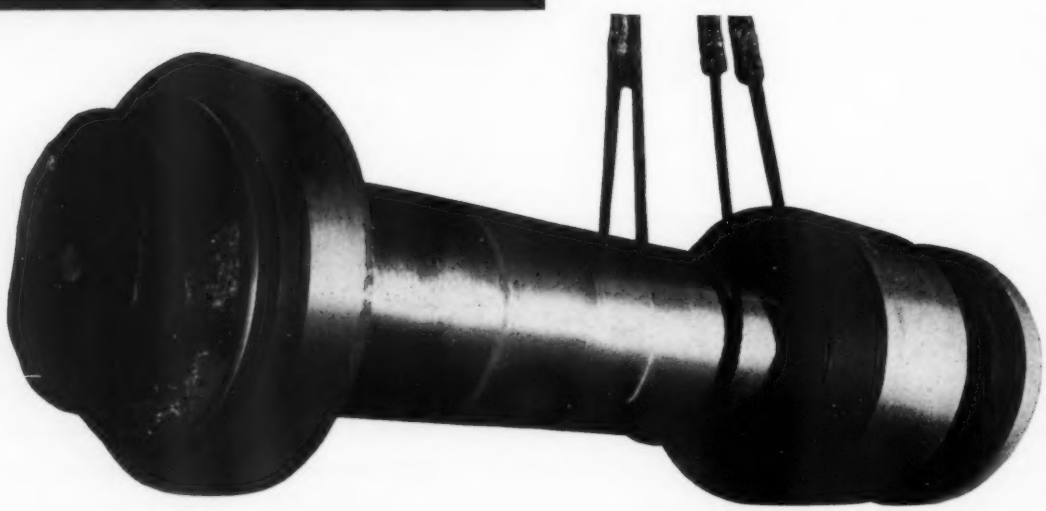

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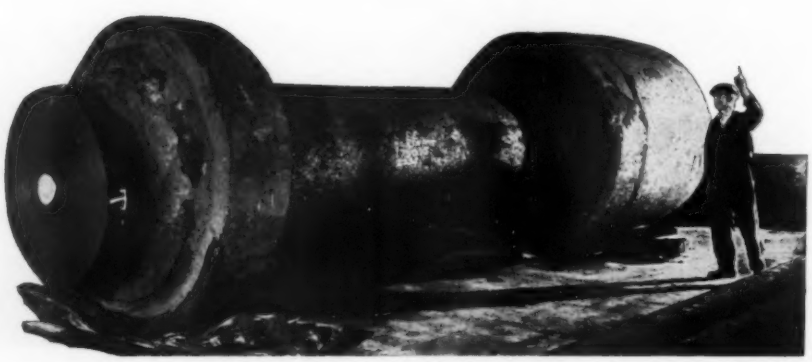

Illustrations show a forging operation under a 7,000 ton electro-hydraulic press, rough machined and black forged steel Turbine shafts, 22' 11" long, 3' 8" diameter with 6' 2" and 6' 4" diameter couplings—Weight as forged 111½ tons, rough machined 70 tons—for a modern hydro-electric power project.

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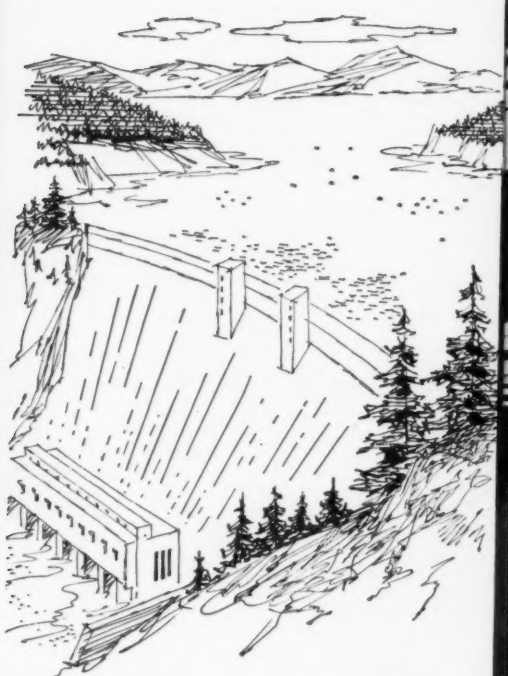

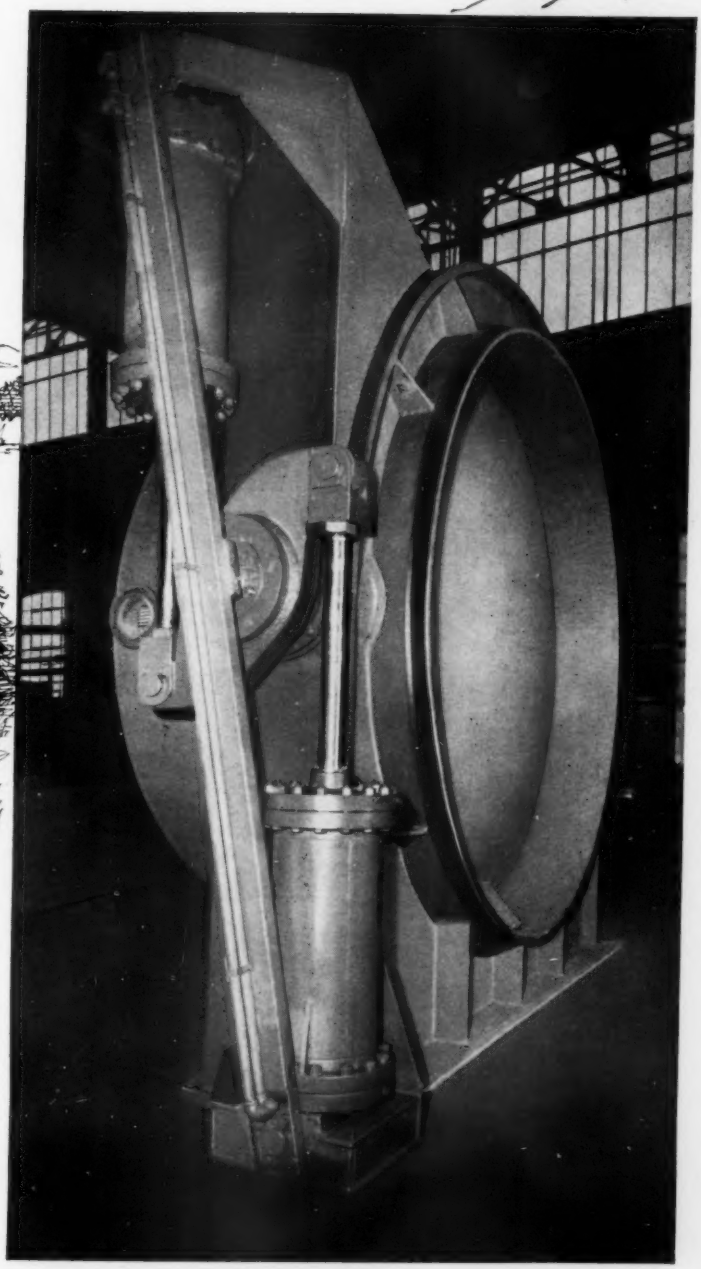

Designed for 80 p.s.i. water pressure and emergency closing against flow of 1,680 C.F.S. under 123 ft. head, the illustration shows a shop photo of one of three 12'-0" Turbine Shut-off Butterfly Valves built for a progressive mining Company in Quebec.

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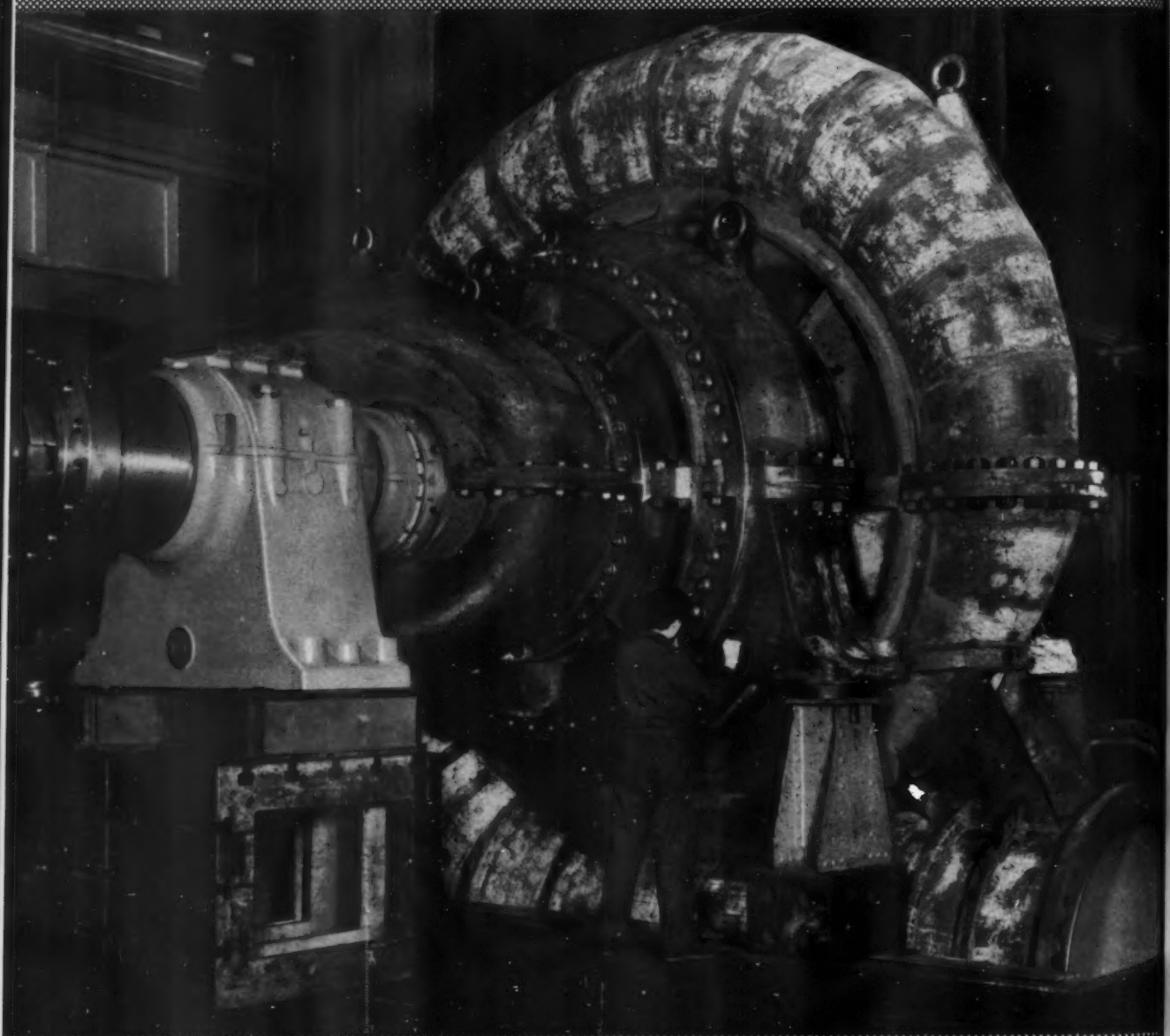

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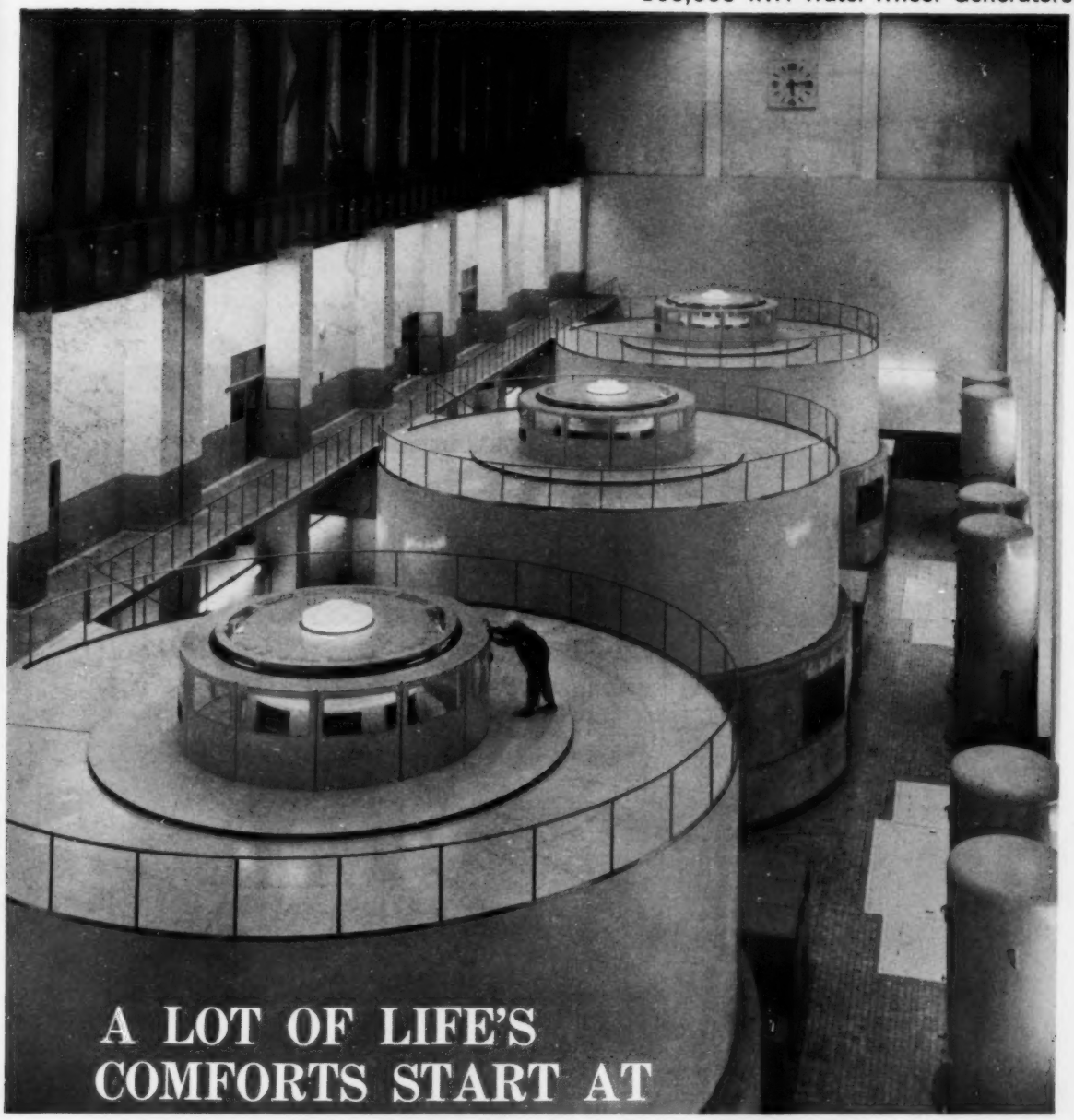

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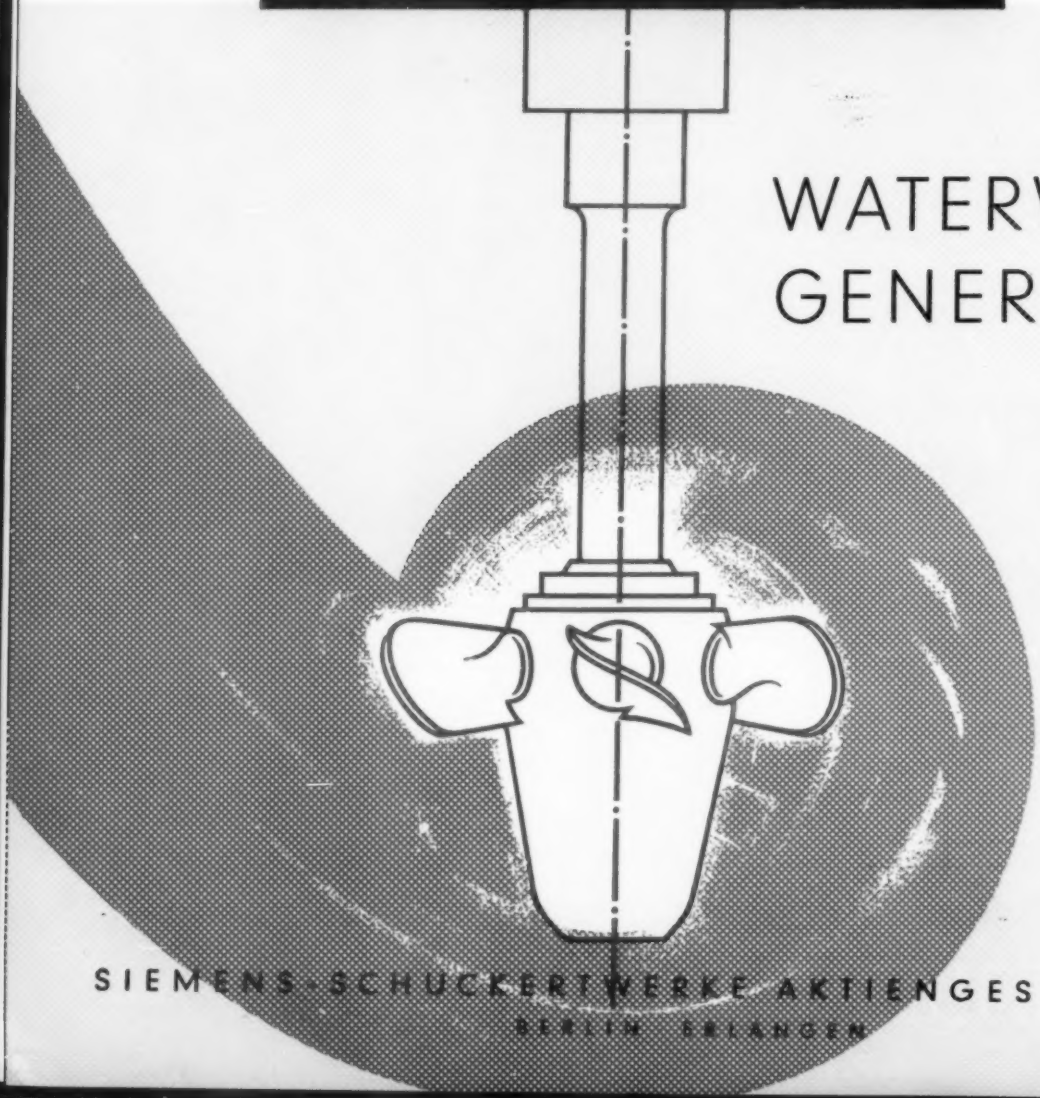

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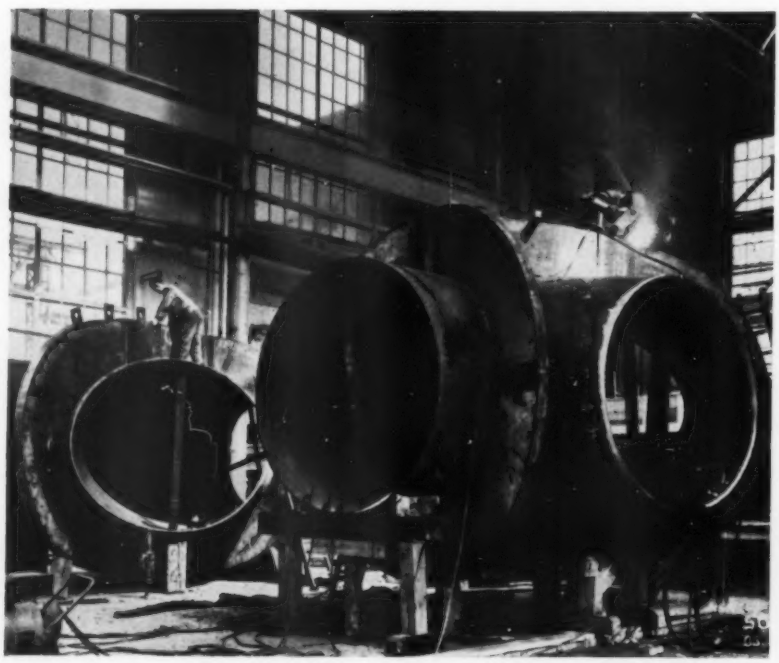
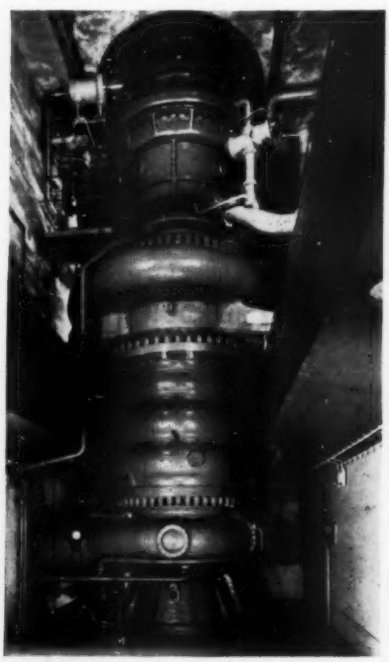


Fabrication of two branch pipes for Ffestiniog in the Sulzer shops at Winterthur. Inside diameter 7 ft. 6 in., service pressure 590 lb. per sq. in.



Sulzer five-stage high-lift pump in an Austrian power storage station. Discharge 49,250 g. p. m., head 3,186 ft., input 55,500 H. P.

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Sweden's Water-Power Prospects

THE economic balance between water power and thermal power in countries employing mixed systems is becoming a delicate one in many cases, and the balance is further complicated by the addition of nuclear power on the thermal side. In recent years the cost relationship between thermal and hydro power has often been radically altered by tendencies for fuel prices to drop and for money to become dearer. In our April issue the Leading Editorial was devoted to the possible future developments in Finland; now a Swedish study of similar problems has been published,* which makes possible some interesting comparisons. This study has been carried out by an economic-investigation committee, which, at the instigation of the Swedish Government, was set up by the State Power Board to examine in detail the possible future balance of hydro and thermal power, with particular reference to the possible construction programme in 1966–70.

In one main respect the Swedish committee has been more conservative than was the International Atomic Energy Agency when deliberating on the prospects for utilising nuclear power in Finland. The committee considered that the introduction of nuclear power into Sweden's electricity-generating system would not be economically justifiable until the latter half of the 1970s. In its opinion the present trends in favour of conventional thermal stations are so strong that detailed consideration has not been given to the possibility of either conventional-thermal or hydro stations being ousted, economically speaking, by nuclear power before the late 1970s. Thus, as far as the Swedish state-owned system is concerned, the problem for at least the next decade and a half is simply to determine the economic balance between the conventional-thermal and the hydro plants.

Two fundamental factors that are of great importance when considering the economics of mixed systems are fuel costs and the interest rates on capital. Both are discussed with great care in the committee's report. It points out that fuel prices are at present very competitive on the Swedish market, particularly in the case of oil (most of Sweden's condenser power stations can be fired by either coal or oil), and are of the order of Kr. 6·5–7·0/Gcal. However, this situation is regarded as being relatively temporary, and the committee decided on a price of Kr. 9/Gcal as being more realistic for the period under consideration.

Similarly, the committee did not feel that the present rate of interest—about 5½%—for long-term Government loans could be maintained for very much longer, and this view seems to have been based on a general growth in the amount of capital available for investment, which seems to be such a feature of the "affluent society." Although the committee records that it felt some doubts in proposing an interest rate which is about 75% higher than that ruling in the early 1950s, it nevertheless found sufficient reasons to recommend a rate of 7% for the future.

The appreciable improvements in thermal-power efficiencies and capital costs have been taken into account; a mean annual thermal efficiency of 36% and a capital cost of Kr. 550/kW are considered as the probable values for the purpose of the study. Rather surprisingly, it is considered that the capital costs for hydro developments are likely to be kept within narrow limits, as much store is set by the savings resulting from improved construction techniques. It is noted that the State Power Board still has a large number of schemes in the planning stage for which the capital costs may only amount to about twice those for modern steam stations.

The economic balance between thermal and water power has been assessed by means of the "water-power development factor," which is defined as the relation between the water-power production in an average year and the primary consumption of electric energy. Earlier estimates based on much higher fuel costs and low interest rates gave an optimum development factor considerably above 110% for the

* "Optimum Balance between Water Power and Thermal Power in the State Power System in Sweden," 29E of Blue-White series, Swedish State Power Board, Stockholm.

State Power Board's system. Using the committee's assumptions, the optimum development factor will fall to about 110% during most of this decade, but only after the completion of the more expensive hydro schemes in the late 1960s and the 1970s, is it estimated that the optimum development factor will fall to 100% or lower.

The report brings out the importance of this yardstick, and shows that small deviations from the optimum development factor produce a larger effect on capital costs than on production costs. Thus, a change in the development factor of 10% from the optimum point would only raise the total annual production costs of the system by about 1%, but it would entail an increased capital cost of about 15% for new plant. By the 1965 stage of development this would be equivalent to about Kr. 6–7 million per annum.

Another interesting conclusion is that, although the demand for electrical energy will continue to grow in Sweden during the next few decades, there are indications that there will be a retardation in the rate of growth in the 1970s, particularly as a result of the competition of cheap fuels with electricity for heating purposes. The committee's maximum forecast is 6·5% per annum, which is even less than the estimated rate of growth for Finland of 8%. This assumption, in combination with the falling optimum development factor, would probably result in a continued high level of water-power development, but with a reduction in the rate of development.

As a result of this very thorough study, the committee was able to put forward a forecast of the State Power Board's requirements up to 1975, based on a range of annual increase in demand in the period 1965–80 of from 1,450 GWh to 2,000 GWh. This shows that a water-power production of from 32·2–38·0 TWh may be required, and that the thermal output capacity may rise to as much as 2,500 MW from a 1965 figure of 450 MW.

It has not been possible within the compass of this Editorial to cover all the many points of interest that are discussed in the Optimum Investigation Committee's report, which should provide a very sound basis for the Swedish State Power Board's detailed planning over the next two decades. From the hydro engineer's point of view, the report offers further authoritative evidence to show that the time has not yet come for the wholesale displacement of water power by modern thermal plant, even in a country that has been energetically developing its hydro resources for some considerable time.

World Bank Loan to Ceylon

THE World Bank recently granted a loan of $15 million to Ceylon for power supply and transmission works, which will include the 50-MW hydro-electric station at Norton Bridge on the Kehelgamu River and an addition to existing steam plant. A 95-mile long transmission line from Laksapana south to Galle will also be financed by the loan. Other transmission and distribution facilities will be undertaken along the coast north of Colombo.

The projects will form part of the power system operated by the Department of Governmental Electrical Undertakings, which covers an area of about 3,500 sq miles. The effective generating capacity of DGEU's present system is 74·5 MW, and power demands on the system have been growing at an average annual rate of 11·5% during the past five years, and are expected to rise to 15% per annum in the future. When it is completed in 1964 the Norton Bridge scheme is expected to meet the anticipated demand, but in the meantime an additional set at the Grandpass thermal station is urgently required to avert a power shortage in the near future.

The Norton Bridge scheme will complete the development of the Kehelgamu River, the waters of which are already utilised by the Laksapana scheme.

Tanganyika's New Scheme

CONSTRUCTION work has recently commenced on the Hale project on the Pangani River in Tanganyika. This scheme, which is expected to cost £4,750,000, was originally intended to start in 1956, but was postponed for financial reasons. Since then the scheme has been redesigned in order to give a higher degree of utilisation, and the capacity will now be 21 MW. Thus the total plant capacity of the Pangani River stations, including the existing one at Grand Pangani Falls, will be 38·5 MW, and it is stated that there is further potential available for development on the river.

It is expect that Dar es Salaam will be supplied entirely by hydro-electricity when the new scheme is completed in 1964. The finance for the project is being loaned by the Colonial Development Corporation and the Government of Tanganyika.

English-Channel Power Cable Laid

THE 160 MW underwater cable link between England and France has now been laid across the Straits of Dover. Manufacture and installation of this link have been shared equally by the two countries under the aegis of Electricité de France and the Central Electricity Generating Board. Transmission is by high-voltage direct current, and the installation consists of two single-core cables laid side by side, operating respectively at +100 kV and −100 kV to earth, giving a voltage of 200 kV between terminals. To prevent interference to ships' compasses it was essential to lay the cables about one metre apart, and each country laid its own pair of cables to mid Channel, where the respective pairs were subsequently joined together.

The two cables for the British section were manufactured respectively by British Insulated Callender's Cables Limited and Associated Electrical Industries Limited, and are of the impregnated-paper-insulated solid type. The conductor has a cross section of 0·525 in² and consists of stranded copper wire lapped with an electrostatic screen. It is sheathed with lead alloy protected against corrosion by vulcanised-rubber tapes, and is armoured with a single layer of 0·232-in galvanised-steel wires with appropriate beddings and servings. Anti-twist tapes are applied over the lead sheath and under the anti-corrosion protection to prevent damage to the cable under excessive tension during recovery.

The CEGB 2,700-ton motor collier *Dame Caroline Haslett* was specially equipped to lay the cables from Dungeness to the middle of the Channel, and, as recorded earlier in this journal, laying trials were carried out in 1958.

The link is expected to come into commercial operation in December, after the land installations,

including the converter stations and transmission lines, have been completed and the necessary trials carried out.

The total cost of the link will be about £4½ million, and it is estimated that each country will save about £170,000 per annum from the facilities it will afford in load sharing.

Civil Engineering Research Council Formed

THE Civil Engineering Research Council was recently set up by the Institution of Civil Engineers, the Federation of Civil Engineering Contractors, and the Association of Consulting Engineers, with the aim of co-ordinating civil-engineering research work in Great Britain. At present, research in this field is carried out by a number of organisations such as the various contractors' research laboratories, the universities, and the Department of Scientific and Industrial Research, and the new Council hope to co-ordinate the various efforts of these bodies for the greatest good of the profession as a whole. New research projects will be initiated, and the Council will endeavour to raise funds by contributions from the industry. The DSIR will also give financial support and will be represented on the Council. Another important function of the Council will be to ensure that the results of research work are made available to the profession through appropriate publications.

Roseires Contract Awarded

IT has been announced by the Ministry of Irrigation and Hydro-Electric Power of the Republic of the Sudan that the contract for the construction of the Roseires dam on the Blue Nile has been awarded to Impresit-Girola-Lodigiani of Milan, Italy. The main purpose of this dam will be to augment the country's irrigation resources, although provision will be made for the eventual installation of a power station.

The dam is to be constructed across the Blue Nile at the Damazin rapids about 500 km south of Khartoum, and about 200 km upstream of the existing Sennar dam. It will consist of a central concrete buttress section, about 1,100 m long, with earth embankments on either side. The total length of the structure will be some 16 km, and the maximum height above foundation level in the main river channel will be about 60 m. A deep-sluice section will be incorporated in the concrete dam at the site of the main channel, and the sluices will be provided with five tainter gates, each approximately 6 m wide by 10 m high. There will also be a surface-spillway section containing seven tainter gates, each about 12 m in height and 10 m wide. The sluices and spillway have been designed to discharge a total peak flow of 17,350 m^3/sec. A service power station, with two 1,000-kW sets, and headworks for a future irrigation canal have been incorporated in the design.

Provision for a future power development is to be made by the formation of an intake section containing seven intakes. The intakes and transitions to the future 6·5-m diameter penstocks will be constructed, and then sealed off by temporary bulkheads. The power station, which will be sited at the toe of the dam, is to be designed for seven 25-MW generating units, of which one will be a standby. It is not known at present when the station will be installed.

The first-stage function of the dam will be to provide additional storage for the Sennar dam, which commands the existing major irrigation areas; at a later stage, the Roseires dam will supply the proposed Kenana irrigation scheme, which will comprise an area of some 1,200,000 acres. The initial storage level of the Roseires reservoir will be 480 m above sea level, at which elevation a volume of 3,000 million m^3 will be retained. Later the dam will be raised by 10 m to give a storage of 7,600 million m^3.

Preliminary contracts for the construction of a road and rail bridge, an airfield, housing, and roads are already under way, and it is hoped to commence the main contract towards the end of this year. The World Bank and the International Development Association have made a combined loan of $32·5 million towards the cost of the scheme, and a loan from the Federal German Government is also expected. The consulting engineers to the Ministry of Irrigation and Hydro-Electric Power of the Republic of the Sudan are Sir Alexander Gibb & Partners, London, and A. Coyne et J. Bellier, Paris.

Japanese Project Completed

THE Okutadami project on the Tadami river in the Fukushima Prefecture of Japan is to be commissioned this month. This scheme forms part of the integrated hydro-electric development programme for the Agano river basin. The Okutadami dam, which is stated to be the largest in Japan at present, is a concrete gravity structure, 157 m high and 475 m long, and it will provide a storage of 458 million m^3. The plant capacity is 360 MW and the average annual output will be 534 GWh. Construction work commenced in 1955, and the estimated cost of the project is about $110 million.

About 15 km downstream of Okutadami is the Tagokura station, which has a storage of 370 million m^3 and will eventually have an installed capacity of 380 MW. These stations will be described in an article on Japanese developments to be published in an early issue.

Comparative Costs of New Zealand Power Schemes

THE New Zealand Minister of Electricity recently gave some figures that compared the estimates of cost for the present development programme, which includes the Cook Strait cable link, with the alternative of developing new schemes in the North Island.

The cost of the present programme was estimated to be as follows: Completion of Benmore, £4 million; construction of new Aviemore station (near Benmore), £15·4 million; construction of Kopuriki station, £7 million; Cook Strait cable link, £18.8 million, of which the cable itself will cost less than £3 million; total £45·2 million.

The alternative North Island development includes three schemes that have an output equivalent to the Waitaki River schemes and the proposed Kopuriki station, and their total cost is estimated to be £76 million. In addition, £9 million would be required for extra transmission facilities.

The difference in basic capital costs of the two schemes of some £40 million would lead to increased capital charges between now and 1969 of £5·4 million. At the same time, if there were no link, there

would be idle capacity at Benmore for many years, and a very conservative estimate puts the total standing charges for the idle plant at £4 million. Furthermore, possible savings of coal over the first few years of operation of Benmore could amount to £3 million. Thus, the only available North Island alternative to the present programme, based on the Cook Strait cable link, would cost an additional £40 million plus extra standing charges and running costs of £12·4 million.

Swedish Turbine Contracts

THE Örebro Elektriska AB has placed an order with Karlstads Mekaniska Werkstad, of Sweden, for a 68,000-h.p. Kaplan turbine to be installed in the Krokströmmen plant on the river Ljusnan in Sweden. The machine will operate at a maximum head of 59·5 m, which is one of the highest utilised for a Kaplan. The Swedish State Power Board has a Francis turbine with a maximum output of 175,000 h.p. from the same firm. This machine will be installed in the Gallejaure power station on the Skellefte river, and the operating head will be 78 m.

Conference on Fluid Machinery

THE Working Committee for Fluid Machinery of the Hungarian Scientific Society for Mechanical Engineering is celebrating the tenth anniversary of its formation by organising a Conference on Fluid Machinery, to be held in Budapest on January 11–12, 1962. The following subjects will be discussed: (1) Consumption of energy during the operation of pumps and fans; (2) Wear, corrosion, erosion and cavitation during the operation of turbines, pumps and fans; (3) Automatic operation of turbines and pumps; (4) Pressure fluctuations in turbines and pump penstocks. Further particulars may be obtained from Mr. László Prockl at the Society's headquarters, Budapest V, Szabadság Tér 17, and applications to attend should be sent in by September 1. Lectures, to last not more than thirty minutes, are invited within the specified field. A single-page summary should be forwarded in the first instance, followed by the full text of the lecture before October 31.

International Construction Equipment Exhibition

THE International Construction Equipment Exhibition was held on June 15–24 at Crystal Palace, London, and provided a good example of the value of open-air exhibiting of this type of equipment, which was of a genuine international variety. Much of the plant was demonstrated effectively on the proving grounds and, although the predominating good weather was an asset in most respects, an occasional fall of rain might have provided a sterner test for the earthmoving equipment!

The exhibition was sponsored by The Federation of Manufacturers of Construction Equipment, The National Federation of Building Trades Employers, and The Federation of Civil Engineering Contractors.

Hydraulics Research in 1960

The 1960 Annual Report of the Hydraulics Research Board of the Department of Scientific and Industrial Research, with which is incorporated the Report of the Director of Hydraulics Research, makes most interesting reading and testifies to the wide variety of work being carried out at the Hydraulics Research Station.

The Board comment on the need for further basic research, and draw attention to the problems involved in the selection of suitable scales for certain model investigations. They suggest that a significant saving in floor space and costs might be achieved if a small reduction in the scales of some models cou'd be made, and have recommended that basic research into the optimum scales for models of various types should be carried out. Another recommendation was made for further research into flow measurement by means of weirs and flumes of various proportions.

The work of the Hydraulics Research Station is described under the main headings of Hydrology, Hydraulic Structures, Uni-Directional Channel Flow, Estuaries, Waves and Sea Defences, and Instrumentation and Mechanisation. Although many of the individual model tests are not of obvious interest to hydro-electric engineers, a substantial proportion are of direct concern. In the field of basic hydrology, experimental work on the unit-hydrograph theory continues, together with studies of the frequency of flooding and the rainfall/stream-flow relationship for a small experimental catchment.

Studies of individual projects included a continuation of the model work for the Ffestiniog pumped-storage scheme; this has involved an examination of designs for the dissipation of the energy of jets from turbine relief valves, and the testing of the effects of a blockage of the pump screens. Three models will be utilised for the study of the Kainji dam on the River Niger, which will form part of a multipurpose scheme embracing power, irrigation, flood control, and navigation; the models will be of a reach of the river channel, the spillway, and a power-station unit. A third study in this field is of an air-regulated spillway syphon.

Other experiments include the design of wave-protection works for the Mangla dam. It is interesting to note that a variety of fabricated blocks were tested under storm conditions, but eventually it was concluded that riprap would provide the most effective solution. An account is also given of the Mauritius wave-power scheme (see WATER POWER, July 1961, p. 254).

The 80-page report concludes with a list of the research papers published during the year; these papers and the report may be obtained from Her Majesty's Stationery Office, York House, Kingsway, London, W.C.2.

GKN House. The Guest, Keen & Nettlefold Group of Companies has built a handsome office block at 22 Kingsway, London, W.C.2, on the site of the old Stoll Theatre, in which it has been possible for the first time to accommodate all the London office staffs of the members of the Group. The new building comprises a ground floor and seven upper floors, having a total area of 92,100 ft², in addition to a basement and sub-basement affording garage accommodation, and a boiler basement.

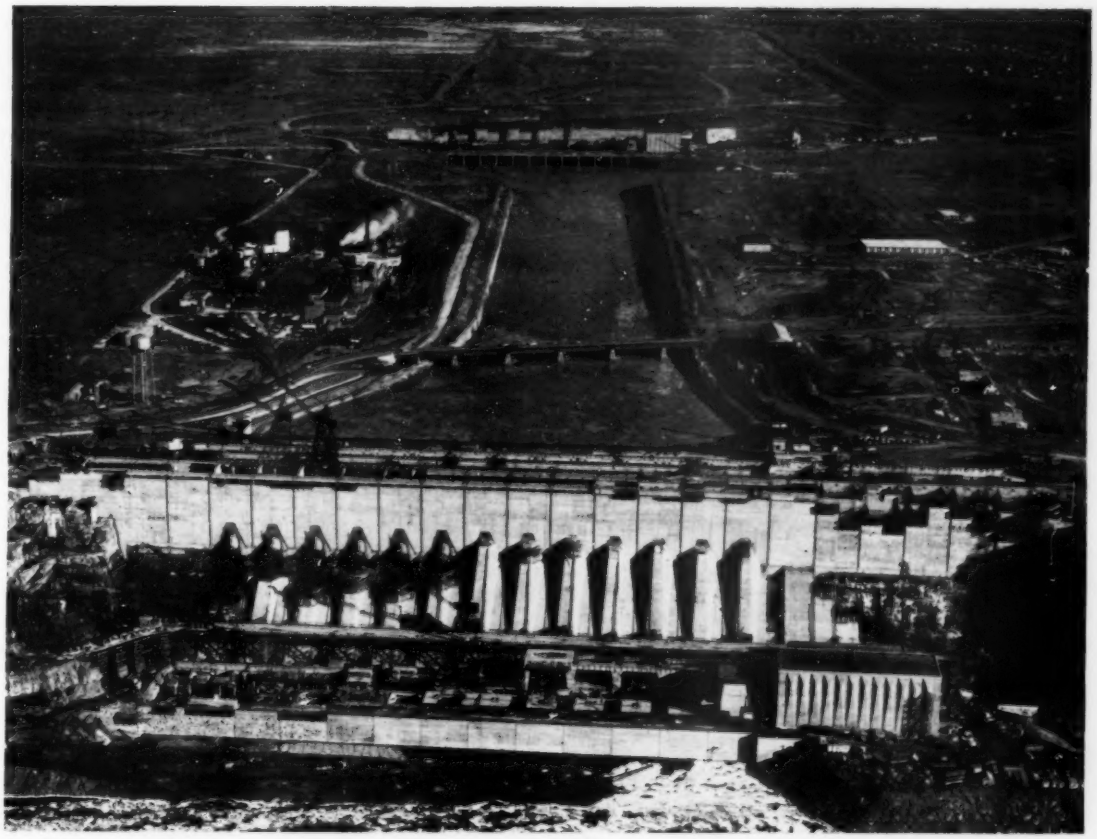

Fig. 1. Aerial view showing the Robert Moses Niagara Power Plant in the foreground, the flooded power canal, and the Reservoir Pump-Generating Plant under construction in the background (January 1961)

The American Niagara Development

A brief account is given of the main features of the Robert Moses Niagara Power Plant and the Reservoir Pump-Generating Plant on the American side of the Niagara Falls

THE State of New York Power Authority's new power station on the Niagara—the Robert Moses Niagara Power Plant—was inaugurated last February, and it is expected that all its 13 generators will be on the line by next spring. The associated Reservoir Pump-Generating Plant (formerly called the Tuscarora Plant) will commence operation next year and will come into full commission in 1963. When completed, the combined installation will have a capacity of 2,190 MW; this, it is believed, will be the largest in the western world, the runner-up being Grand Coulee at 1,947 MW. Indeed, the American Niagara's lead over Grand Coulee is due to the presence of the pumped-storage plant, which has a generating capacity of 240 MW.

The size of the main units in the Robert Moses station also calls for comment, for these machines, rated at 150 MW, are amongst the most powerful in the western world. They are equalled, in fact, only by those at Chute des Passes, Bersimis, and Stornorrfors. The transformers are on a similar scale, for each forms a unit with its generator and is rated at 180 MVA.

In our August 1960 issue we published an article* describing the civil-engineering constructional work in hand on this scheme, and our present purpose is to give an account of the development as a whole, to supplement the more specialised information given in the previous article.

Modern developments on the Niagara must always be assessed in the context of the American-Canadian treaty of 1950, which is designed to preserve the

* "The American Niagara Power Project," by Ian B. Mackintosh, WATER POWER, August 1960, p. 295.

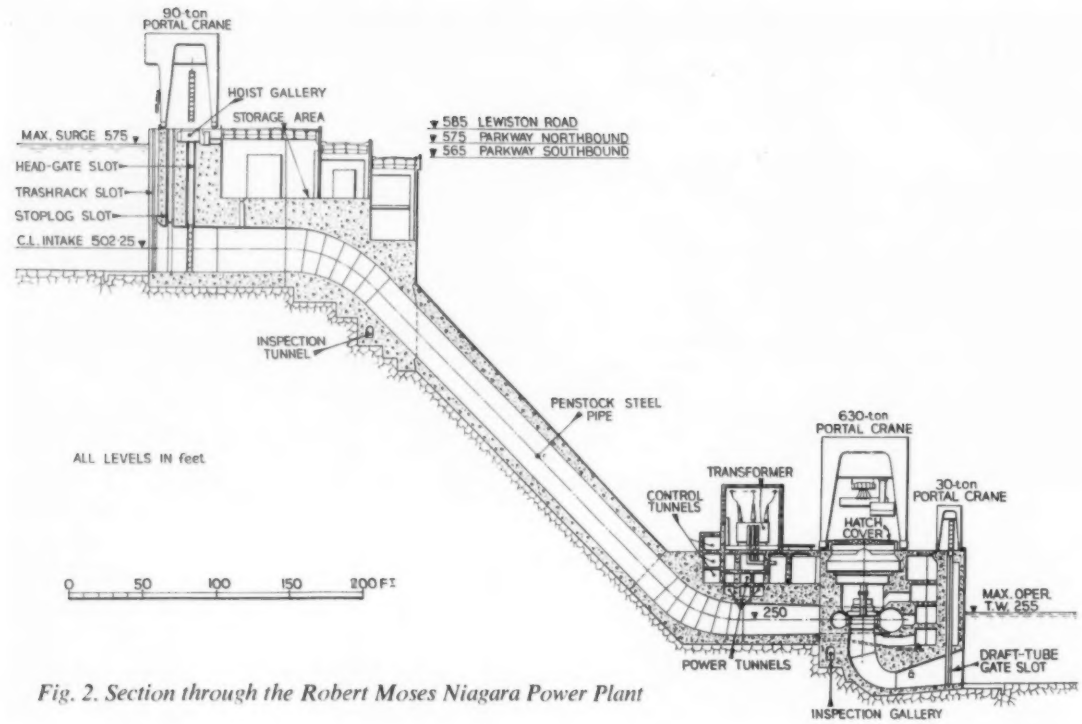

Fig. 2. Section through the Robert Moses Niagara Power Plant

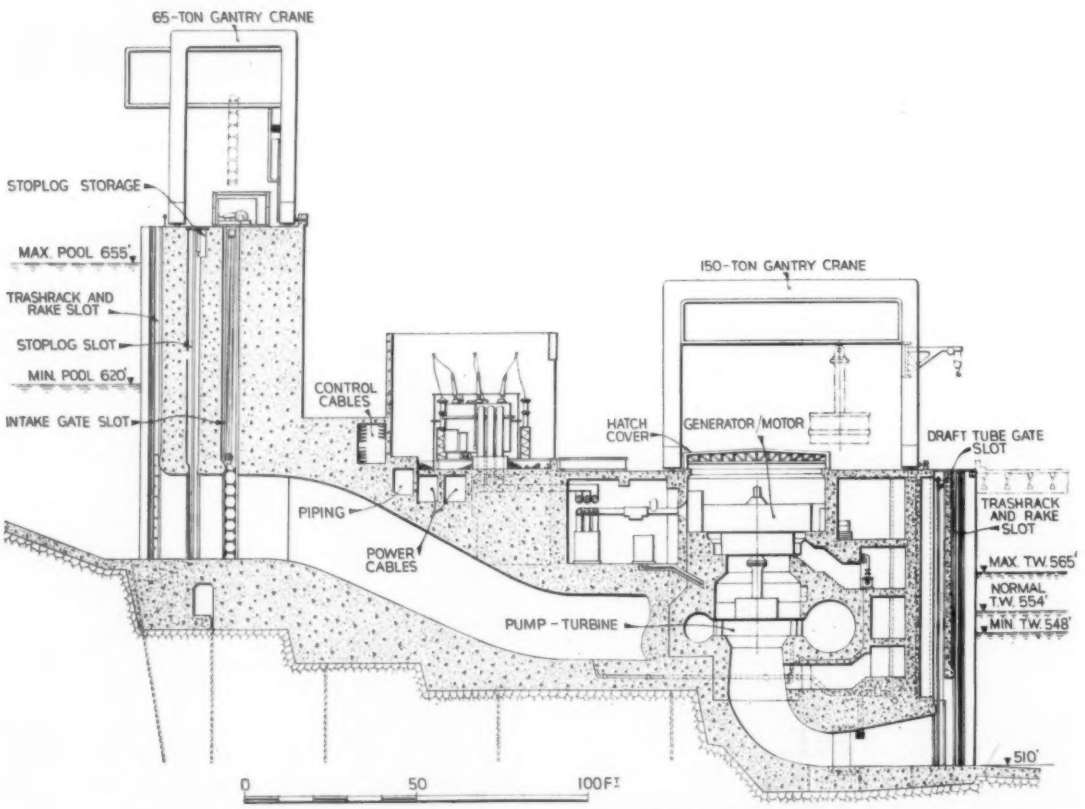

Fig. 3. Section through the Reservoir Pump-Generating Plant

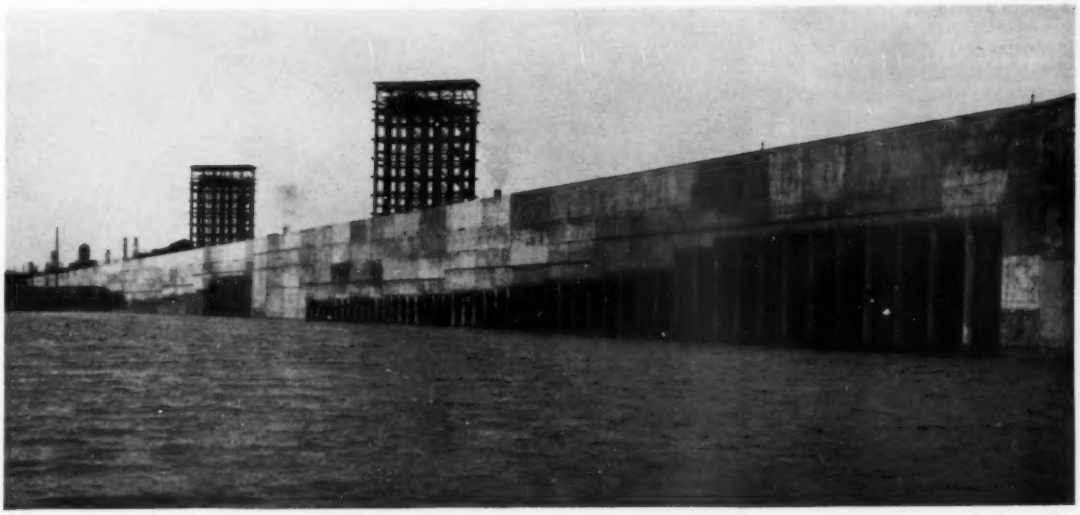

Fig. 4. The river intakes, with the gate structures behind

scenic beauty of the famous Niagara Falls while allowing the two countries to share in the fullest possible exploitation of the flow. In accordance with this treaty, a minimum flow of 100,000 cusecs must be maintained over the falls in daylight hours during the tourist season (April 1 to October 31); at other times the flow may be reduced to 50,000 cusecs. The average natural river flow is 202,500 cusecs and is remarkably even, the maximum flow being only about twice the minimum. Canada has already built the Sir Adam Beck No. 2 plant† under the 1950 treaty, and the Robert Moses station is the American counterpart.

The heavy demand for power on both sides of the river naturally calls for the maximum utilisation of the water available above the treaty limits, and the ideal solution has been found in pumped storage. The pumped-storage plant at Sir Adam Beck No. 2 has already been described in this journal‡, and on the American side the equivalent installation is the Reservoir Pump-Generating Plant, as it is called.

The project is expected to cost $720,000,000, or $329 (£118) per installed kilowatt, and it should generate 13,000 GWh per annum. It will have a firm power of 1,800 MW even when considered in isolation, but a 250-mile interconnection with the Authority's station on the St. Lawrence Seaway will increase the firm power of each project, because flow in the St. Lawrence is normally high in the summer when the treaty restrictions on the Upper Niagara are most onerous.

† "The Sir Adam Beck Niagara G.S. No. 2," by Richard Hearn, WATER POWER, July 1956, p. 246.

‡ See also "The Mixed-Flow Variable-Pitch Pump-Turbine," by Paul Dériaz, WATER POWER, February 1960, p. 49.

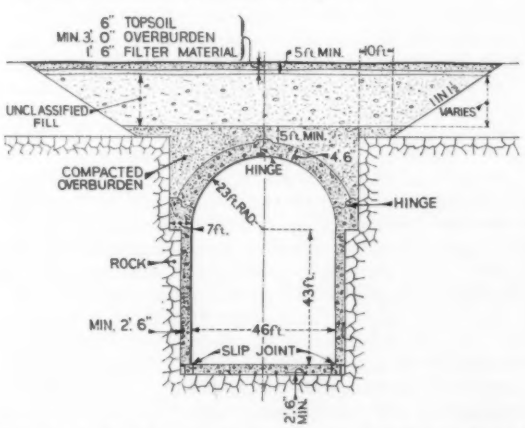

Fig. 5. Section through one of the water conduits

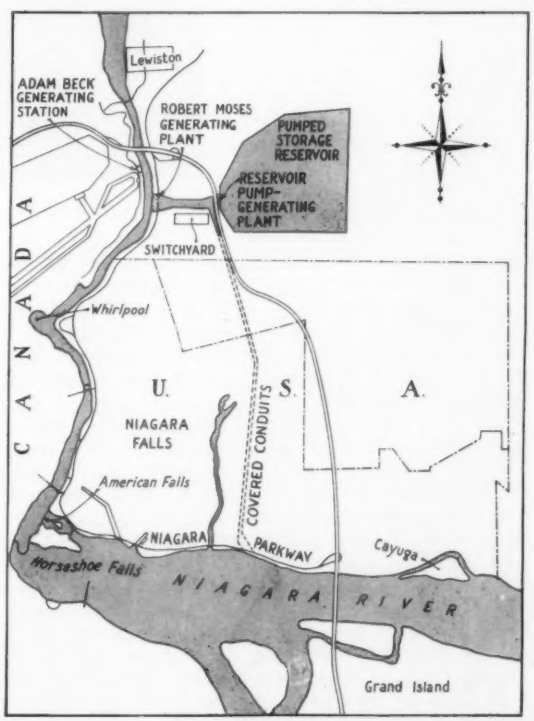

Fig. 6. Map of the American Niagara development

The Power Authority financed the $720,000,000 cost of the project by the sale of bonds to private investors, who will be repaid with interest from revenue received from the sale of power. No tax money or government credit was involved.

Layout of the Development

A map of the project area is given in Fig. 6. The drop at the Niagara Falls is 160 ft, but rapids above the falls offer a further 50 ft of head and the rapids below the falls 115 ft. The intake has therefore been arranged above the upper rapids and the tailrace below the lower rapids, so that the station utilises a gross head of 314 ft out of the 326-ft difference of level between Lake Erie and Lake Ontario.

The intake is located 2½ miles above the falls at the foot of Hyde Park Boulevard in the city of Niagara Falls. It consists of two reinforced-concrete structures (Fig. 4) each 700 ft long and supplying a separate covered conduit. Each intake contains 48 slotted openings, the tops of which range from 13 to 26 ft below the river surface. To draw adequate water from the intake the river bed has been dredged over an area of nearly half a square mile, and a rockfill dyke, 2,000 ft long has been built from the point of Buckhorn Island, opposite the intake, to direct the flow of the east channel of the river towards the intake.

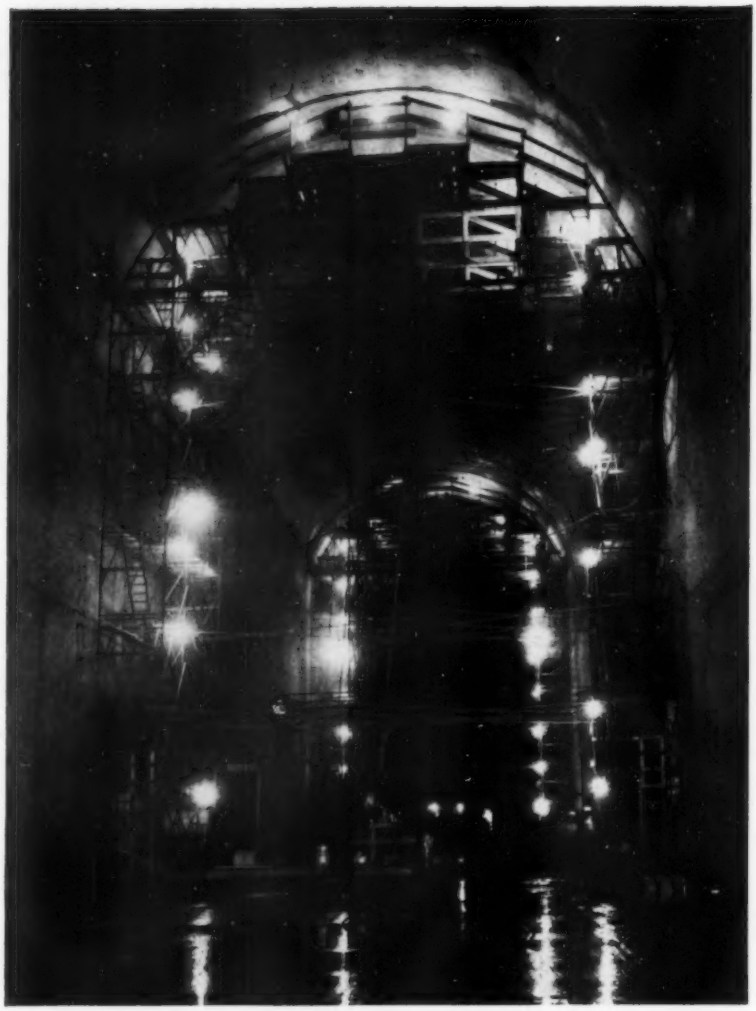

Fig. 7. At work in one of the water conduits

At the junction between each intake and its conduit is a gate structure 55 ft wide by nearly 100 ft high, carrying a vertical-lift gate 49 ft wide by 68 ft high. Grooves are also provided for stoplogs, and an underground stoplog storage chamber is located between the gate structures.

The twin water conduits are disposed at a centre distance of about 200 ft and are about 4¼ miles long. They were constructed by cut-and-cover, and as will be seen from the section, Fig. 5, their design is based on a three-hinged arch, which can accommodate itself to any movement arising from rock squeeze. Each conduit is 46 ft wide and 66 ft high to the crown of the arch, and together they can carry 83,000 cusecs at a velocity of 14 ft/sec. The concrete walls and floor have a minimum thickness of 2 ft 6 in; the haunches supporting the arch are 7 ft thick, and the arch sections are 6 ft thick at the base and 5 ft thick at the crown. The tops of the conduits average 40 ft below the ground surface.

The discharge from these conduits enters an L-shaped pond comprising a transition section about 1,800 ft long embracing the forebay of the Reservoir plant on the right, and a channel 500 ft wide, 110 ft deep and 3,000 ft long, leading to the forebay of the main generating plant. This pond not only provides a common supply for the two plants but also acts as a surge basin.

Robert Moses Niagara Generating Plant

A section through the Robert Moses Niagara generating station is given in Fig. 2, and aerial views are shown in Figs. 1 and 9. An intake structure terminating the forebay just mentioned admits water to 13 penstocks, each of which supplies a generating set in a semi-outdoor power station at the foot of the cliff. The intake structure is of reinforced concrete and consists of 13 blocks, each containing trashracks, stoplog slots, and two 25 ft by 29 ft 7 in vertical-lift gates. All the movable equipment is handled by a 90-ton portal crane.

The penstocks are of welded construction. Each has a straight length of 462 ft and a diameter of 24 ft.

Fig. 8. Inside one of the river intakes

An elbow at the top reduces from a diameter of 28 ft 6 in at the intake to 24 ft at the commencement of the straight portion, and a second elbow at the bottom further reduces the diameter to 21 ft where it meets the scrollcase extension. The penstocks are encased in concrete, and the upper and lower elbows are secured in concrete anchor blocks.

Each generating set consists of a vertical Francis turbine, rated at 200,000 h.p. at a net head of 300 ft and driving a 150-MW, 3-ph, 60-c.p.s. generator at 120 r.p.m. These units are disposed below the top deck of the power-house block and are protected by removable hatch covers. Erection and servicing are carried out with the aid of a 630-ton portal crane. Each turbine draft tube can be closed by three vertical-lift gates, each 15 ft 4 in wide by 20 ft high, handled by a 30-ton portal crane.

Each generator is connected to its own transformer,* the 13 transformers being arranged on a concrete deck built over the penstock lower anchor blocks. Each transformer is a three-phase unit rated at 180 MVA, but as the station supplies the switchyard at two voltages, seven of the transformers step up from 13·2 kV to 230 kV and the remaining six to 115 kV.

Reservoir Pump-Generating Plant

To form the upper pool for the Reservoir Pump-Generating Plant a reservoir of 60,000 acre-ft capacity is being enclosed by means of a rockfill dyke with a compacted earthfill core. This dyke averages 55 ft high, 40 ft wide at crest, 260 ft wide at base, and 33,000 ft long. The surface of the pool is 80 ft above that of the main pond, referred to high-water level in both cases.

As will be seen from the section, Fig. 3, the layout of the plan is generally similar to that of the main generating plant, allowing for the difference in the respective heads. The installation will comprise 12 reversible pump-turbine units running at 112·5 r.p.m. Each pump-turbine will be rated to discharge 3,400 cusecs against a net head of 85 ft when working as a pump, and to develop 28,000 h.p. at 75 ft head as a turbine. Each electrical machine will be rated at 37,500 h.p. as a motor and 20 MW as a generator. The transformers, which will be three-phase units rated at 100 MVA, will be mounted on a deck above the penstocks.

Switchyard and Tie Line

As will be seen from the map, Fig. 6, the switchyard occupies a 35-acre site south of the power pond and midway between the Robert Moses and the Reservoir plants. The yard is divided into three voltage sections: 115, 230 and 345 kV. Seven 115-kV circuits and six 230-kV circuits are brought in from the Robert Moses plant, and four 230-kV circuits extend to the Reservoir plant. All these circuits are carried by oil-filled cables run in underground cable galleries.

In the 115-kV section there are 33 oil circuit breakers, each of 10,000-MV rupturing capacity, and 78 isolators; in the 230-kV section there are 26 oil circuit breakers of 20,000-MVA rupturing capacity, and 48 isolators; and in the 345-kV yard there are four 25,000-MVA oil circuit breakers and 15 isolators.

The 115-kV and 230-kV sections are interlinked by means of two 200 MVA auto-transformers, and the 230-kV and 345-kV sections by two 400-MVA auto-transformers with provision for a third unit.

* See "The Robert Moses Niagara Transformers," WATER POWER, March 1961, p. 118.

Fig. 9. Aerial view looking across the river over the Robert Moses Niagara Power Plant to the Sir Adam Beck No. 2 Generating Station on the Canadian side

The 345-kV section feeds the Niagara St. Lawrence tie line, which is double-circuit from Niagara to Rochester 70 miles away, and single-circuit to a point north of Utica, a further 130 miles. There the line ties in to an existing 230-kV facility at Niagara Mohawk, which connects to the Authority's Adirondack substation 70 miles south of St. Lawrence, to which the connection is completed by an Authority-owned 230-kV line.

Contractors

The main civil-engineering contractors were enumerated in the article in our August 1960 issue, and we give below the manufacturers of the mechanical and electrical equipment:

ROBERT MOSES NIAGARA POWER PLANT
Penstocks ($10,992,000)
Chicago Bridge and Iron Co.

Turbines ($20,686,400)
Baldwin-Lima-Hamilton Corp.
Newport News Shipbuilding and Drydock Co.

Generators ($20,119,910)
Westinghouse Electric Corp.

Transformers ($3,935,700)
Ferranti Electric Inc.

RESERVOIR PUMP-GENERATING PLANT
Penstocks ($892,800)
Chicago Bridge and Iron Co.

Pump-Turbines ($11,291,350)
Allis Chalmers Mfg. Co.
S. Morgan Smith

Generator-Motors ($7,157,995)
Allis Chalmers Mfg. Co.

Transformers ($1,001,420)
Brown Boveri Corp.

SWITCHYARD
Buildings and Electrical Work ($7,982,743)
Emerson-Garden Electric Co.
Day & Zimmerman.

Acknowledgment

This article is published by permission of the Power Authority of the State of New York, whose collaboration in its preparation is gratefully acknowledged.

Mobile Crane. The Rapier 1520 mobile crane is described in a very informative pamphlet by Ransomes & Rapier Limited, 32 Victoria Street, London, S.W.1. The 1520 can handle loads up to 15 tons, and its maximum jib length is 80 ft. The pamphlet gives complete details for the potential customer.

New Truckmixer-Agitator. Blaw Knox Limited, Rochester, Kent, England, have sent us a pamphlet describing their new Varispeed truckmixer-agitator, which is supplied in two sizes with capacities of 4/4½ and 6/6½ cu yard. One of the features of this model is its hydrostatic drive.

Floating-Type Sector Gates

New developments in the design of floating-type sector gates permit stable and accurate control at all gate positions and under all conditions of relative headwater and tailwater levels

By H. ROBOHM and K. PETRIKAT*

IN order to control floating-type sector gates there must be an adequate head from the headwater to the sector chamber and from the chamber to the tailwater. In time of flood, if the head between headwater and tailwater is almost balanced, the head between the sector chamber and the tailwater approaches zero, or it may even become negative, i.e. the sector floats upwards. This article describes an outlet design by means of which the required pressure head is brought about for all water levels and sector-gate positions. The vacuum created at the outlet of the control channel makes it possible to lower the sectors even with a very high tailwater. By installing stabilising cells in the top of the sector, any accumulation of air in the sector chamber is avoided. Thus the sector is controlled smoothly, and rising of the sector as a result of air pockets is eliminated.

The Hemelingen Gate

Stimulated by an American design, M.A.N. designed and built for the Bremen municipal authorities the first sector gate in Germany as long as 50 years ago. It was the Weser weir at Hemelingen, which is still in service today in its original form, and under normal operating conditions fulfils its tasks perfectly. When water levels are unusual, however, the sectors cannot be brought into their lowest position by means of standard control mechanisms, and special measures are necessary, which make operation more difficult; as a result the type of sector gate used at Hemelingen was not considered absolutely reliable in Germany. During the following decades a number of sector gates were built in other countries, particularly in northern Europe; although these gate installations were in accordance with the same basic principle, and, as a result of the more favourable hydraulic conditions prevailing there, are still in perfect condition, attempts have since been made to overcome the difficulties encountered at Hemelingen by providing a fundamentally different control system.

It was only when work had started on the large hydro-power schemes at Geesthacht on the Elbe, Landesbergen on the Weser and in the Moselle valley (for which sector gates had been planned from the outset for operational and aesthetic reasons) that the basic principle of the Hemelingen sector gate came into its own again in Germany, as the reasons for the difficulties encountered at Hemelingen were now discovered and eliminated by a series of improvements.

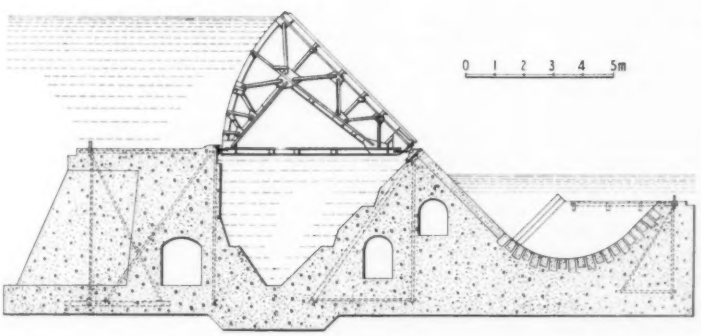

Fig. 1. Cross section through Hemelingen sector gate

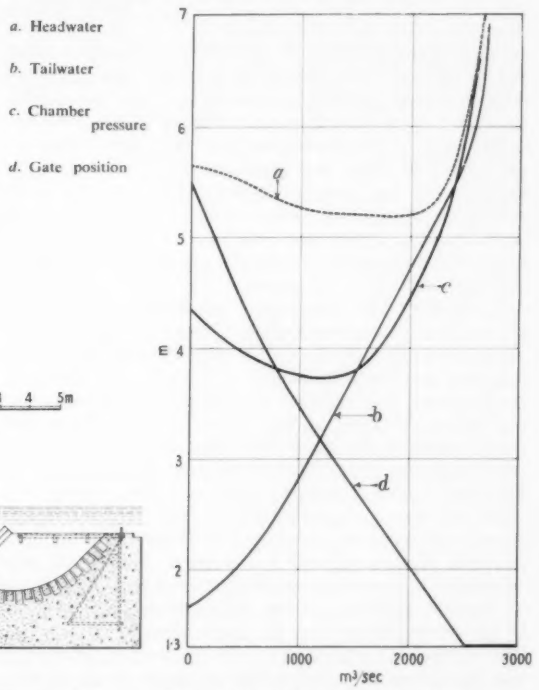

Fig. 2. Hemelingen calibration curves

For a better understanding of the new sector-gate control, it seems appropriate to study the Hemelingen sector gate first (Fig. 1). The gate structure is hook-shaped in cross section and consists of a skinplate,

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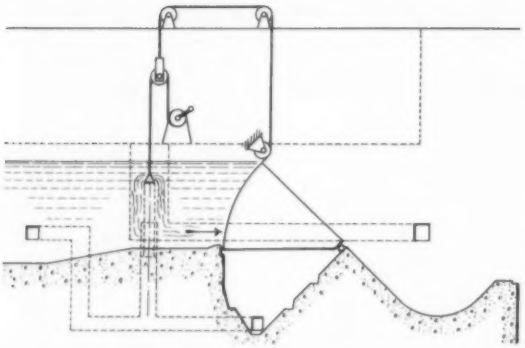


Fig. 3. Tubular gate control with restoring mechanism at Hemelingen

forming a circular arc with the gate hinge located in the centre, and of a straight overflow plate, and is open at the bottom. Thus, together with the appropriately designed foundation, it forms a chamber enclosed on all sides, which can be filled with water through channels from upstream and emptied into the tailwater. The discharge is controlled by a hand-operated tubular gate, the elevation of which determines the pressure of the water in the chamber. The pressure exerted by the water in the chamber from below against the overflow plate produces an upward torsional moment which must be in equilibrium with the opposing torsional moment brought about by the dead weight, the pressure of the tailwater acting on the overflow plate and the load of the overtopping water when the gate is at rest. The water pressure acting on the curved skinplate from outside and inside, however, does not produce any torsional moment, since the resultant of the water pressure passes through the centre of rotation.

Control of the sector gate would be very easy if the internal pressure required to maintain equilibrium dropped steeply as the sector gate descended. In this case the tubular gate would only have to be brought to and held in a definite elevation, corresponding to the desired sector-gate position, when the sector gate would settle at the level corresponding to the position of the tubular gate. The equilibrium would be stable, since, if the sector were deflected downwards, the upward torsional moment determined by the tubular-gate position would be greater than that required for the new position; the excess would therefore constitute a restoring moment, which would force the sector gate back again into the desired position.

However, if we plot for each sector-gate position the corresponding chamber water level required for the equilibrium position, the diagram given in Fig. 2 is obtained. As the sector-gate crest descends, the curve of the internal pressure also drops initially, but after having reached a minimum value it rises again as a result of the increasing load of tailwater and overtopping water. This characteristic curve cannot be achieved with the simple type of tubular gate control already described. In the first part of the curve the equilibrium is stable, but the flatter the gradient of the curve subsequently becomes, the smaller is the restoring moment, falling to zero at the lowest point. Here the equilibrium is indifferent; deflection of the sector gate would not produce any restoring moment and the sector gate would remain in the position reached. In the subsequent part of the curve the equilibrium of the sector gate actually becomes unstable, since deflection here causes a negative restoring moment. In this region the internal pressure as set by the tubular gate is not sufficient to maintain the equilibrium when there is a downward deflection, and the sector gate will drop.

Control of the sector gate by simple adjustment of the tubular gate is thus inadequate, since on the one hand there is no clear relation between internal pressure and sector-gate position, and on the other hand the equilibrium of the sector gate is not stable in all positions unless further auxiliary means are employed.

In view of these conditions, Plate developed for the Hemelingen weir a tubular-gate control with a restoring mechanism. As a result of the restoring action, the movement of the sector gate is transmitted to the tubular gate position in such a manner that the change in chamber pressure counteracts the gate movement (Fig. 3). A criterion for the stability of the sector gate in a certain position is the value of the restoring force which, in the case of a deflection caused by external effects, brings the gate back into

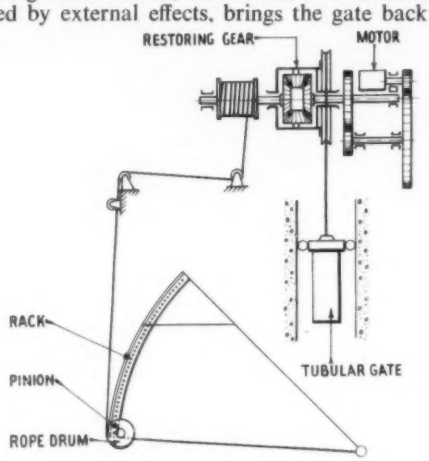


Fig. 4. Rack and pinion mechanism for the Holmen gate

its desired position. The greater the adjustment of the tubular gate caused by the restoring mechanism at a given deflection of the sector gate, the greater is the restoring force and the greater, therefore, is the stability of the sector gate. This was clearly recognised in the design of the Hemelingen sector gate, but for structural reasons it was necessary to choose a relatively low transmission ratio, so that the sector gate was relatively "yielding." In the Hemelingen case the sector-gate movement is transmitted to the tubular gate by a block and tackle at a ratio of 1 : 2. With this control, if it is desired to lower the sector by a given distance from a given position, the tubular gate must first be lowered by a predetermined amount. This reduces the internal chamber pressure and starts the downward movement of the sector. The descending sector now transmits its movement through the restoring mechanism to the tubular gate in the opposite direction, and maintains the movement until by lifting of the tubular gate the internal pressure has risen again to such an extent that it stops the downward movement of the gate.

The diagram in Fig. 2 shows that in the upper

Fig. 5. Holmen sector gate being assembled at the works

sector positions the water level in the chamber is lower than the sector crest. In this region therefore a free water level with an air cushion on top builds up in the chamber. If the water level in the chamber is decreased in order to lower the sector, the latter does not at first follow the falling water level in the chamber, but only when the forces acting on the sector in a downward direction have overcome the static friction of the seal. Then the sector suddenly follows, and since sealing friction in motion is only half as great as the static friction, there occurs a force which affects the control, thus causing the sector gate to jerk.

This was also taken into account by Plate in the design of the Hemelingen weir. At his suggestion water-jet pumps were installed in the sector to draw the air from the upper space of the sector body, thus raising the water level in the sector as far as the sector tip. In this way a positive transmission of the drive forces to the sector body is guaranteed. The sector should now follow the control pulses without time lag, and jerky movements would be eliminated.

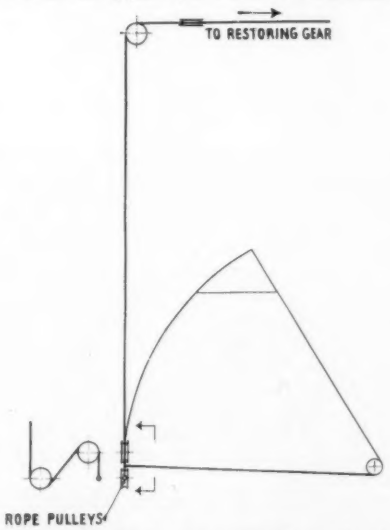


Fig. 6. Geesthacht gate-control mechanism

To ensure positive transmission of the operating forces these water-jet pumps must not get clogged and thus fail to remove the air completely from the tip of the sector. If a small quantity of air is left in the tip, the pressure variations of the water-jet pump affect the sector and cause slight hunting of the sector in accordance with the pressure-fluctuations; this can eventually induce wear of the seals. For such a hydraulic control to be in a state of permanent readiness, there must be an adequate head between the headwater and the controllable pressure level in the sector chamber and from there to the tailwater, in all operating positions and at all possible levels of the headwater and tailwater. At Hemelingen, however, this condition is not fulfilled. As a result of the shape and low dead weight of the sector body, the curve of the internal chamber pressure is lower over its entire course, and from a certain lowered gate position onwards it is crossed by the relatively high tailwater (Fig. 2). Consequently, from this sector position downward, there is no longer any head between the chamber and the tailwater, and the sector cannot be lowered any further by means of the tubular gate.

This was clearly recognised in the case of the Hemelingen weir, and an attempt was made, by means of a suitable arrangement of the outlet of the tubular-gate well into the stilling basin, to bring about an ejector effect in order to counteract the backflow of the tailwater. Sometimes, however, flow conditions are such that as a result of the to-and-fro movement of the standing wave, pressure variations are caused, which are transmitted to the tubular-gate well and impede proper operation. In these circumstances the sector must be controlled by careful manual operation of the inlet and outlet valves of

the tubular-gate well; as there is no restoring mechanism, however, this can only be achieved under constant supervision by an experienced man.

Hence, for lowering the sector into the lowest position and, above all, in order to keep it there, a further measure was applied, which makes use of the suction zone behind the flooded sector crest. In the region of this suction zone, flaps are arranged in the overflow plate, which are opened when the gate is to be fully lowered, causing the water to be sucked away from the chamber and the pressure to drop below tailwater level. This manoeuvre is also complicated and requires the tubular gate to be raised above tailwater level, so that the tailwater will not flow back via the tubular gate into the chamber when the flaps are opened. A further disadvantage is that the drawing off of water by way of the flaps cannot be regulated, and the sector, therefore, drops into its lowest position.

In conclusion, it may be said that although in the Hemelingen design all essential features were correctly assessed, not all the measures taken in this first design proved adequate. The 1 : 2 transmission of the restoring action is insufficient, since the sector is too resilient. The tide fluctuations of the tailwater have a considerable effect on the sector position. The desired effect of the built-in water-jet pumps is not completely achieved. There is still an elastic air cushion above the water inside the sector, which gives rise to jerky movements of the sector during control operations. The ejector effect at the appropriately designed tubular-gate outlets is not reliable. The suction flaps of the overflow plate do not allow control of the sector in the lowest positions. The experience of Hemelingen has been of great value, however, in developing the design and construction of the sector gates built by M.A.N. in the succeeding years in the northern countries, all of which operate basically on the same principle (Figs. 4 and 5), and the sector gates recently built in Germany are based on the same principle.

Fig. 7. Conical side plates of Geesthacht gate

The following fundamental conclusions are based on the experience gained at Hemelingen:

(1) The restoring action of the control mechanism must be achieved mechanically and positively by the sector movement. Any restoring gear that requires an outside source of energy for its operation, e.g., electric current, hydraulic oil, compressed air, involves a risk of failure, which could have the most far-reaching consequences.

(2) The restoring action must be achieved at an adequately high transmission ratio, so that the sector position is influenced as little as possible by a change in the external loads.

(3) A free water level with an air space inside the sector is unacceptable, since it disturbs accurate control of the sector; an enclosed air space in the sector tip, without connection to the atmosphere, can be very dangerous, since it produces buoyancy and prevents the sector from reaching its lowest position.

(4) In all operating positions and in all the water-level conditions occurring in service, there must be an adequate pressure head from the headwater to the chamber and from there to the tailwater, so that the sector can be moved at any time without outside energy.

(5) The sector must be so heavy that, in the event of failure of the suction devices intended to reduce the internal pressure in the chamber below the tailwater pressure, it does not float upwards.

Restoring Mechanism

In the right-hand sector gate at Hemelingen it proved to be particularly necessary to provide a higher transmission ratio for the restoring mechanism, since this sector had to be fitted with an automatic float-operated water-level control equipment. An attempt was first made to achieve this higher ratio mechanically. The rotation of the sector was to be transmitted from the gate-hinge extension in the pier to a gear, which in turn was to transmit the sector movement, measured at the crest, to the tubular gate at a ratio of 1 : 4. It was found, however, that with this system the elastic deformations of the transmission elements were too great and would have disturbed the control. The mechanical restoring device by means of a block and tackle at a ratio of 1 : 2 was therefore retained in this sector also, but an electrically operated restoring mechanism was added to this sector, increasing the transmission ratio to a total of 1 : 5.

In the sector gates built by M.A.N. in Norway another method was used, which made possible a higher transmission ratio by purely mechanical means without inadmissible elastic deformations. In these cases (Fig. 4) the sector movement is transmitted by a rack, fixed to the end of the sector on the inside of the skinplate, through a pinion to a shaft, extending through the pier wall into the control room. Owing to the large radius of the rack and the small pitch-circle diameter of the pinion a higher transmission ratio is obtained. Inside the pier a cable drum is fixed to the pinion shaft, from which a cable transmits the rotation to the tubular-gate hoist. The control pulses given manually or electrically are introduced through a differential gear.

The transmission of the sector movement by rack and pinion was retained also at Landesbergen and at Detzem on the Moselle. In the case of Geesthacht this

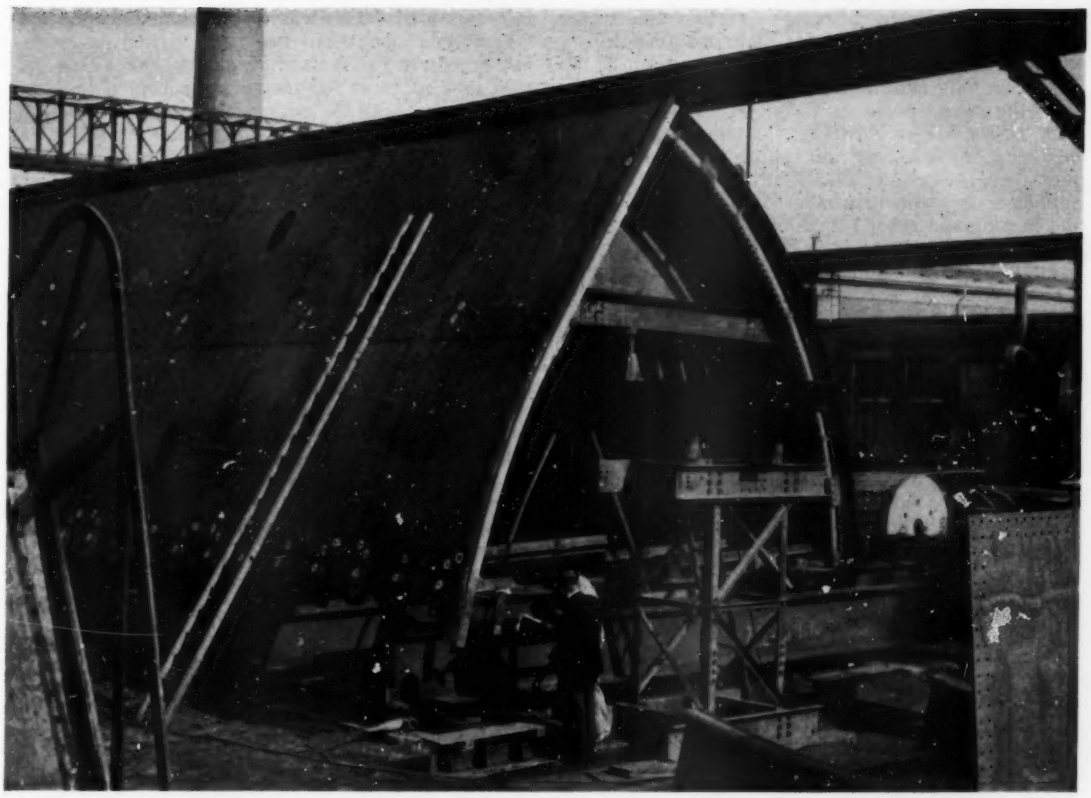


Fig. 8. One of the two Landesbergen sector gates, which are 40 m long and 4·3 m high

method was unfortunately rendered impracticable by the conical end-plates of the sector body, which were used here at the express wish of the owner, and a pulley system was used (Fig. 6).

Use of Stabilising Cells

At Geesthacht a new system was used to prevent the development of an air space above the water in the chamber, with all its attendant disadvantages. In the sector ridge a partition is fitted over the whole length of the sector (Fig. 6), which with the skinplate above and the rear wall forms an enclosed hollow body divided into a number of compartments by the cross-frames required to make the sector rigid. The elevation of the partition is such that in all operating positions it is lower than the level of the water in the sector chamber below. A free water surface, therefore, cannot develop. Air segregated from the water in the chamber is disposed of through vent pipes extending above the crest of the sector. The partition thus ensures positive transmission of the control pulses and effects stabilisation of all control operations. The continuous tier of compartments at the same time gives the gate structure the torsional strength required, so that longitudinal bracing, which would otherwise be necessary, can be dispensed with, and the additional expense for the partition partially compensated by the savings achieved in omitting longitudinal bracing, water-jet pumps and other mechanical equipment for air evacuation.

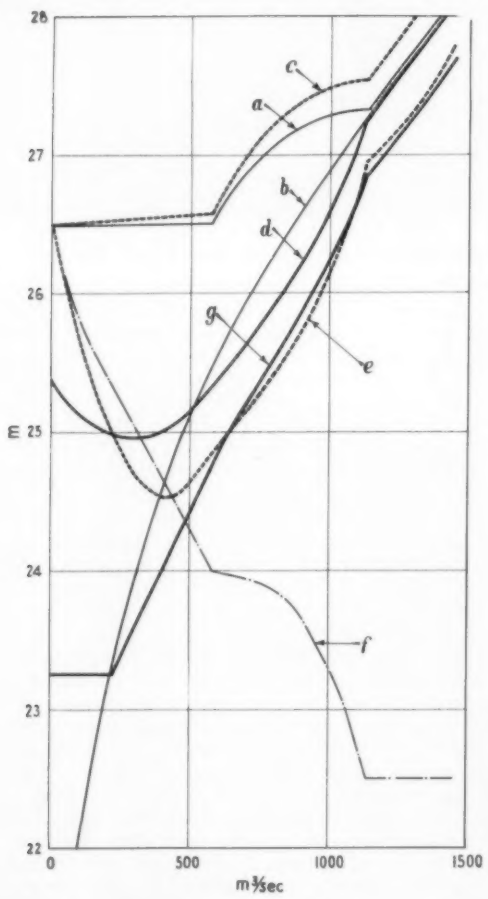
The compartments connect with the headwater and are therefore always full of water. They also make it possible to vary the internal pressure in the chamber (curve shown in Fig. 2) so as to suit prevailing conditions, in order to fulfil the requirement that there must always be a pressure head between the headwater and the chamber and between the chamber and the tailwater. If some of the compartments are kept empty by sealing them off so as to be watertight, the pressure curve moves down; if they are filled with ballast, it moves up. At Geesthacht approximately 8 m^3 of concrete were put in the 50-m long sector, so that, even with the highest tailwater caused by the tide, the lowering of the sectors is ensured without supplementary suction devices. Such ballasting of the sector, however, was criticised on the ground that there was no point in having the gates carry this ballast all the time, as it is only required in rare cases. This opinion is not fully justified, since the ballast is after all only a counterweight balancing an excessive buoyancy and may be compared with concrete counterweights as commonly used in vertical-lift gates. The objection that raising of the sector from the lowest position is made difficult by the ballast lacks conviction, too. If, in fact, prevailing hydraulic conditions were so unfavourable that, in view of the large amount of ballast required in order to avoid undesired floating of the sector, the difference in water level would not be adequate to raise it again, it would be better for the sake of safety to raise the sector with the aid of pumps until the required head was developed, rather than to run the risk of the sector floating upwards at the very moment of maximum discharge. Every sector-gate installation must in any

case be provided with pumps, so that the sector chambers can be emptied for maintenance work. It therefore involves no additional investment if the same pumping equipment is used to raise the sector from the lowest position.

At Landesbergen also (Fig. 8) an intermediate deck has been provided, and the compartments above the intermediate deck are filled with water. In this case supplementary concrete ballast was omitted, since in the meantime a special form of mouth for the outlet pipe had been developed at the M.A.N. Test Station for Hydro-Engineering, ensuring a suction effect where there is an adequate discharge over the sector (Figs. 9 and 10); this effect is permanent without additional control operations, e.g., the opening of suction flaps, being necessary. The decrease in pressure on the overflow plate of the lowered sector, which without the suction effect at the outlet could cause the sector to float, is brought about by the same flow that produces the suction effect; it is therefore ensured that both effects can only occur simultaneously, and unintended floating of the sector is therefore impossible. In addition, for the two Landesbergen sectors, there is also provided a special suction pipe, the installation of which was recommended by the tenderers after model tests had been carried out at the Bundesanstalt für Wasserbau in Karlsruhe. This suction pipe connects the suction zone behind the crest of the sector with the outlet channel below the regulating valve. It can only operate when the sector has been lowered sufficiently, and for this purpose the normal discharge is stopped by a slide valve. The suction pipe thus necessitated a bypass and consequently additional control equipment was required.

Shut-Off Valve Chamber Control System

With regard to the control of the internal pressure in the chamber, a new method had to be used at Landesbergen. With the tubular gate control, as applied at Geesthacht and Hemelingen, only the discharge is controlled, while the inlet valve is permanently open. If the sector is in the highest position, the tubular gate can be raised above the headwater level, so that the pressure in the sector chamber corresponds to the headwater. In this condition the water will not overtop the tubular gate and therefore will not flow through the inflow valve to the chamber. In any other position, however, there is a constant flow through



a, Upstream water level; *b*, downstream water level; *c*, velocity head; *d*, chamber pressure; *e*, pressure drop at top of sector gate; *f*, position of top of sector gate; *g*, pressure drop achieved by attaching a hemispherical suction nozzle to the side of the pier (see Fig. 10)

Fig. 9. Control diagram for Landesbergen gate

Fig. 10. Suction nozzles on Landesbergen gate

the sector, since the top edge of the tubular gate is below the headwater level. Because of the very fine sand in the Weser, it was feared that if such regulating elements with water constantly flowing through them were used the sector chamber would silt up very

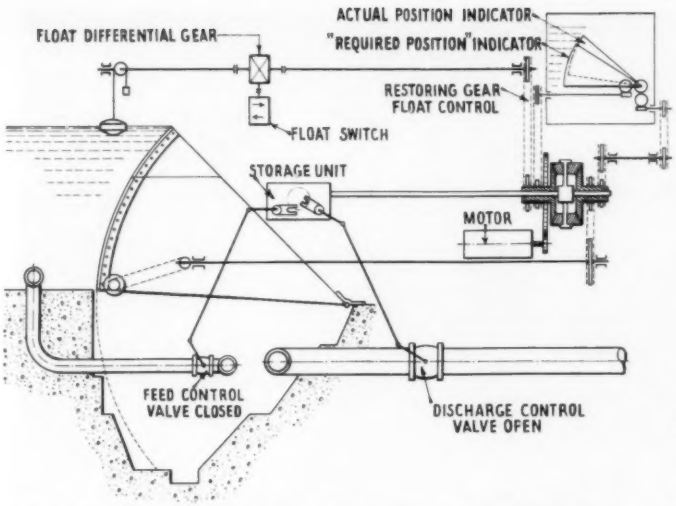


Fig. 11. Control and restoring mechanism of Landesbergen sector gate

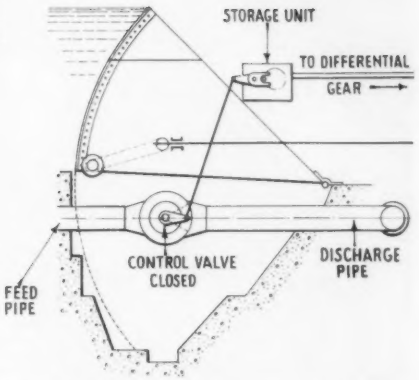


Fig. 12. Control and restoring mechanism of Detzem sector gate

rapidly, and the tubular-gate control was therefore considered unsuitable. Instead, accurately operating control valves (Fig. 11) have been placed in both the inlet and outlet channels. To raise the sector the inlet valve is opened, while the outlet valve remains closed, whereas for lowering, the outlet valve is opened and the inlet valve remains closed. The sector position is therefore determined by the volume of water contained in the chamber, the pressure level in the chamber being determined by the dead weight of the gate and by the water load on the overflow plate. The pressure is thus greatly variable according to the height of the overflow and the tailwater level. To ensure that such changes in pressure do not affect the sector position, it is particularly important in this case that no air is contained in the chamber under the sector, which owing to its compressibility would react to a change in the external load by a change in volume.

In addition, also, this type of control requires a restoring mechanism in order to avoid dropping of the sector when any seal on the tailwater side is damaged. With the leakage loss caused by the damage to the seal, the resultant lowering of the sector will cause the inlet valve to open, until the inflow compensates the leakage. The transmission ratio of the restoring mechanism must be such that normal leakage cannot lead to any noticeable change in the sector position. It is of special importance to ensure that the sector movement is transmitted positively by the restoring mechanism to the valves, and thus is effective in all circumstances. The operation of the valves to maintain the desired position should not depend on any outside energy, failure of which would mean that the sector would get out of control. With the double valve control in each operating position the sector is extremely stable. Thanks to the incompressibility of the water enclosed in the chamber, it does not react to pulsating forces, such as are inevitable when the sector is flooded. Even the external loads that commonly occur in practice, e.g., ice load, cannot force the sector out of its proper position.

With this type of valve control (Fig. 11), as in sectors with tubular gates, the sector movement is transmitted by a rack fixed to the inside of the skinplate at the sector end, to a pinion which is mounted on a shaft extending through the pier masonry into the control chamber. The restoring pulses transmitted by this shaft act through a differential gear on a linkage, which operates the valves in the direction required. The same differential gear also transmits the operating pulses to the valves when it is desired to alter the level of the gate. Since the transmission

Fig. 13. Landesbergen storage unit

Fig. 14. One of the three Detzem gates, which are 40 m long and 6·7 m high

ratio of the restoring gear is very high, and therefore a small gate movement is sufficient to open the respective valve up to the stop, a free-travel device must be incorporated in this control system so that excessive sector travel, as can occur in the case of mechanical damage to the seals or a considerable drop in the headwater level, does not damage the valves or the mechanical transmission elements. For gate operation, too, such a device is important. To avoid damage, it would be possible of course to fit friction couplings, but in the case of this important control element, on the operation of which the sector position depends, a friction drive must definitely be avoided. The problem of the adjusting mechanism was solved in the Landesbergen control system by means of a storage unit. A control cycle thus takes place as follows:

To lower the sector the control motor is switched on for lowering. It operates the linkage of the outlet valve through the differential gear until this valve is fully open. Then the further rotary movement of the control motor is transmitted to the storage unit, and at the same time the sector movement preset by the control pulses is indicated on a "desired-position" indicator. When this indicator has reached the required new position of the sector, the control motor can be switched off. In the meantime the sector has started to move after the outlet valve has opened, and continues to descend until it has covered the distance set by the storage unit, whereupon the restoring mechanism acts on the valve linkage and closes the outlet valve precisely at the moment when the sector has reached the desired position. The whole process takes place positively without friction. The storage unit and the differential gear are housed in an enclosed gearbox and run in oil, as seen in Fig. 13.

This valve control with storage unit was also adopted for the sector gates of the Moselle barrage at Detzem and will also be used for future weir installations on the Moselle (Fig. 14). Here, however, the two separate inlet and outlet valves will be combined in a three-way rotary slide valve at the special request of the owner (Fig. 12).

These improvements, which led to the creation of the fully controlled M.A.N. gate with stabilising cells, showed that it is possible to maintain the water level very accurately by means of a sector gate and to move the sector accurately to within a few millimetres.

Savigliano. A colourful brochure entitled "Macchine Rotanti," describing the full range of their activities in the heavy electrical industry, has been sent to us by Savigliano, of Turin. It includes all types of a.c. and d.c. generators and motors, convertor sets and electromagnetic couplings. The text is in Italian and English.

Prefabricated Buildings. We have received a number of pamphlets from Middlesex Prefabricated Buildings Limited (formerly J. E. Lesser & Sons Limited), of Green Lane, Hounslow, Middlesex, England. These describe the firm's range of sectional timber buildings, which are designed for a wide field of application, including the contracting and allied industries.

Chute-des-Passes Turbines

The author describes in detail the 200,000-h.p. turbines, and their ancillary equipment, installed at the Chute-des-Passes development in Northern Quebec. These turbines were among the most powerful in the world at the time of commissioning

By R. S. MACKAY*, B.A.Sc., D.I.G., Jr.E.I.C.

ALL five of the 200,000-h.p. Francis turbines for the Chute-des-Passes installation, which is owned by the Aluminium Company of Canada, are now in commercial operation. One of these machines, which were designed by the English Electric Co. Ltd., has already developed an output of 246,000 h.p. at part gate under full reservoir conditions, and is thus believed to have exceeded by some 20% the maximum power ever previously generated by a hydraulic turbine outside Russia.

The trend in recent years in the design of hydro-electric stations has been towards the use of large-capacity units. The output of 170,000 h.p. developed by the turbines at Grand Coulee in the USA, which was for many years recognised as a record, was exceeded in 1956 when the Bersimis Lac-Casse turbines achieved an output in excess of 200,000 h.p. A similar output was obtained from a unit at Stornorrfors power station in Sweden in May 1959, and also later in the same year from the turbines at the Bersimis II development in Quebec.

Although the basic design of the Chute-des-Passes turbines is not generally revolutionary, the fact that such a high turbine output has been achieved is itself proof that new ground is being broken, and even larger units may now be considered. The successful extrapolation by the designers of the hydraulic and mechanical details has been accompanied by similar advances in the various manufacturing processes. The wide use of welded construction has suggested better configurations to the designer, and these have led to reduced stresses and to reduced material content. Much design consideration has also been given to the fabrication of turbine runners because of the greater accuracy of control in water-passage form that is possible, as well as the better degree of surface finish. Notwithstanding the advantages of fabricated components there are still specific uses for castings, and the steel foundries, which recognise the trend towards larger units, have expanded and improved their facilities to the point where high-quality runner castings of 30-tons weight, such as those at Chute des Passes, are well within the available furnace capacity.

In keeping with the modern design of large-capacity units is the development of the electrohydraulic governors supplied to control these giant turbines. At Chute des Passes the governor equipment will permit the five units to be operated as a single machine having a capacity of 1,000,000 h.p. Such a method of control is certain to become of even greater importance for system frequency regulation as more and more of the already extensive power systems are interconnected into super grids.

Description of the Project

The Chute-des-Passes development, the civil-engineering works for which were fully described in the May 1959 issue of WATER POWER, is located on the Peribonka River about 100 miles north of Isle Maligne in Quebec. It can contribute 1,000,000 h.p. to the existing Saguenay system of 2,580,000 h.p., which comprises five major hydro-electric plants on the Peribonka and Saguenay Rivers.

An existing dam at Passe Dangereuse, which regulates the flow to the stations on the Peribonka River, impounds the water from a drainage area of 4,787 sq miles, and creates, with the aid of the steep fall of the river downstream, a maximum static head of 640 ft at the Chute-des-Passes station. The controlled flow from an additional catchment area of 1,920 sq miles will be available when the control works and improvements are completed at Lake Manouan.

A profile of the Chute-des-Passes development is given in Fig. 1. The intake control structure is located on the shore of the lake formed by the Passe Dangereuse dam. One of the more spectacular events of the construction work was the initial watering of the intake tunnel, which involved the blowing of a 50-ft high rock plug approximately 100 ft in diameter, after cutting a 120-ft deep sump to catch the rock from the blown plug.

The water is conducted through a 34-ft diameter horseshoe-shaped tunnel nearly 31,000 ft long. Approximately 2,000 ft upstream from the turbine centreline, a surge tank, 130 ft in diameter and 250 ft deep,

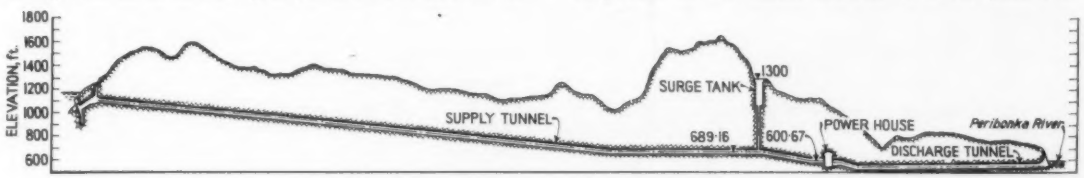


Fig. 1. Profile of Chute-des-Passes development

* Hydraulic Engineer, English Electric (Canada).

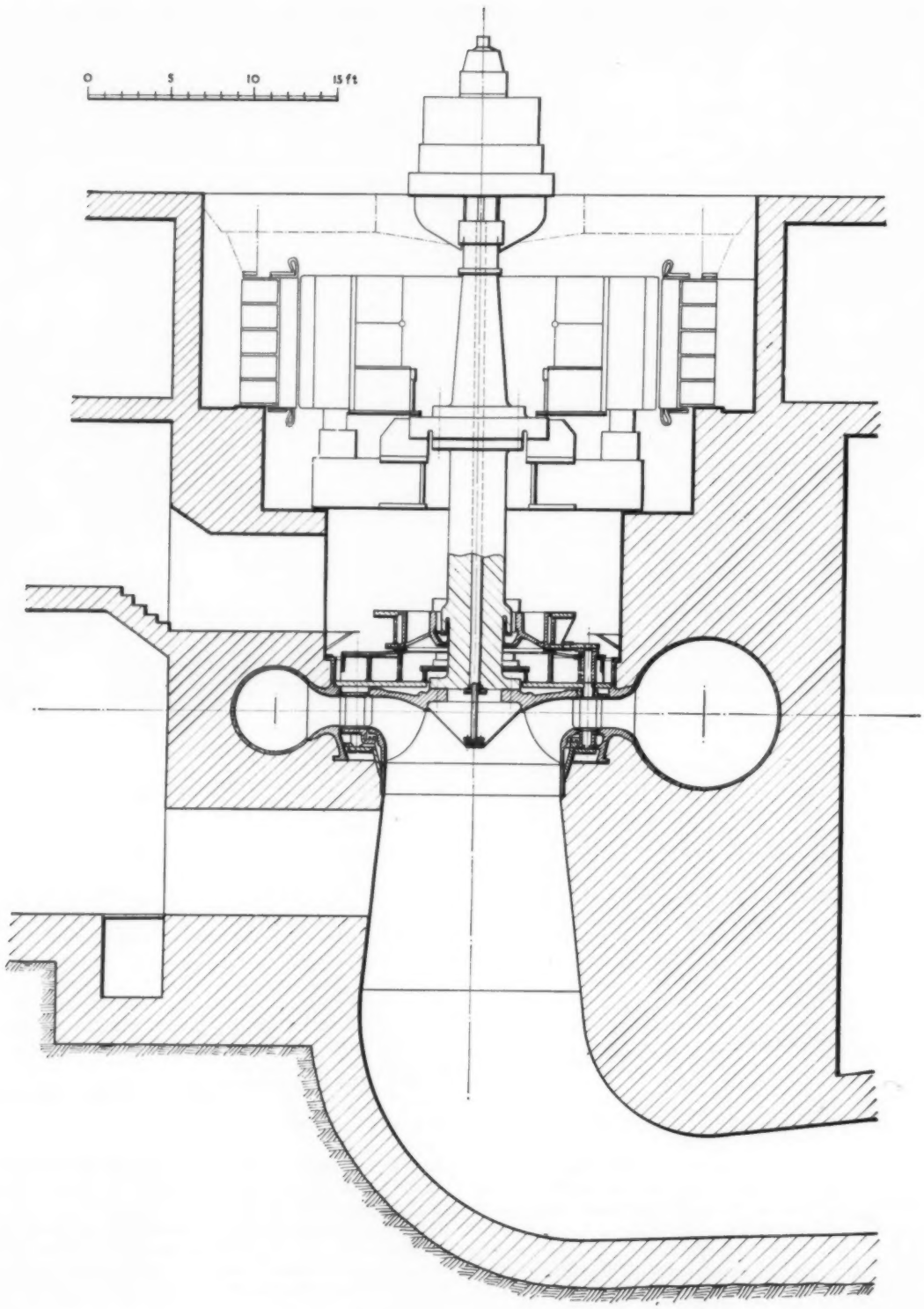


Fig. 2. Section through one of the Chute-des-Passes generating sets

was excavated, together with a retention tank capable of holding 2,000,000 ft³ of water during a total station load rejection. The fully lined tunnel ends in a manifold from which individual penstocks branch off to the five turbines located in the underground power house. This power-house cavity is 473 ft long, 105 ft high and 65 ft wide, and is located 450 ft below the surface. Parallel to the power-house cavity, and almost equal in volume, is the draft-tube manifold, 430 ft long, 60 ft wide and 102 ft high, which functions as a surge tank for the 48-ft diameter unlined tailrace tunnel. The tailrace tunnel operates normally under pressure and extends 9,000 ft downstream from the power house, and actually passes under the Peribonka River before discharging.

The individual penstocks are steel lined, and reduce in stages from 15 ft diameter down to 11 ft diameter at the point where they connect to the penstock valves, which are of the rotary type with servomotors operated from penstock pressure.

The generating equipment consists of five turbines of the Francis type rated at 200,000 h.p. at 200 r.p.m. under 540 ft head, and five umbrella-type generators, which are rated at 165,000 kVA at 60°F temperature rise, and 190,000 kVA at 80°F temperature rise. An extremely compact unit arrangement has been achieved by using a single length of shaft extending from the turbine-runner coupling to the underside of the generator rotor. An impression of this may be had from Fig. 2, which shows a typical cross section through the unit.

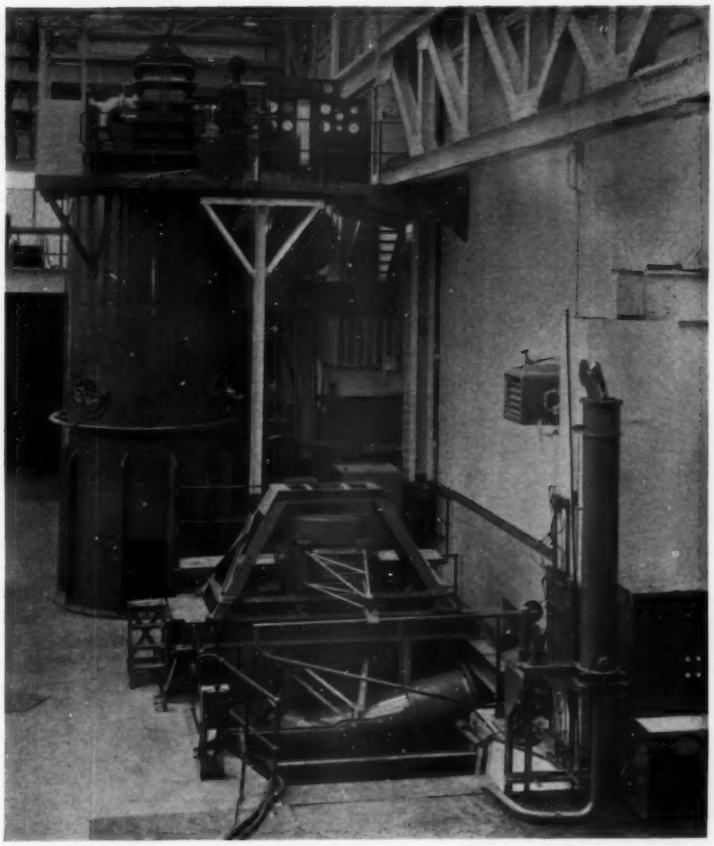


Fig. 3. View of model-turbine test berth with cavitation test stand in the background

Turbine Development and Design

The reservoir level may vary considerably, and, consequently, guarantees of turbine performance were required for a range of heads from 470 ft to 590 ft. Predictions of prototype performance under all conditions were obtained from an extensive series of turbine-model tests carried out in the English Electric hydraulics laboratory at Rugby. A 1 : 6 scale model turbine, complete with fabricated spiral casings, stay-rings, guide vanes, runner and draft tube, was fitted into a test berth similar to that shown in Fig. 3, and accurate measurements of head, discharge, model speed and power developed were recorded for various guide-vane openings.

Model-test characteristic curves were plotted, and, from these curves, predictions of efficiency and power were made for various constant unit speeds corresponding to the specified operating heads. It was necessary to produce and test two different model runners before selecting the final design of water passages that would satisfy all requirements of performance guarantees, in addition to a rather special condition imposed by the surge-tank design.

In order to prevent the possibility of air being drawn into the tunnel through the surge tank, it was necessary, in effect, to limit the slope of the power versus efficiency curve in the region of full-gate operation. The sudden acceptance of load by five machines operating on joint control would create a large demand for water, which initially must be supplied by the surge tank. If this demand exceeded a given rate then the level in the tank would be lowered to the point where air would be drawn in.

When checking the initial design of the surge tank for this condition, turbine characteristic curves were used that were subsequently found to have insufficient margins for performances at part loads. The second model runner provided satisfactory proof that all performance guarantees would be met, but the relationship of power to efficiency in the region of full load would have increased the possibility of drawing air in through the surge tank. Modifications were, therefore, made to the model runner and further testing carried out. The final design was based on the modified second model runner, the tests from which were satisfactory in all respects. This is thought to be the first instance in which the runner design has had to be modified to meet the requirements of the surge-tank characteristics.

A diagrammatic layout of the model-turbine test berth is shown in Fig. 4. Water supply for the test turbine was pumped from the laboratory sump into a head tank fitted with a long weir and spillway to maintain a constant headwater level. Water passed from the head tank to the spiral casing, through the turbine, and out of the draft tube into a long canal. Screens fitted in the canal eliminated large-scale turbulence, and at the end of the canal a rectangular weir without side contractions was used to measure the discharge.

To ensure the necessary degree of accuracy and precision in measuring the various test quantities during model tests, extensive instrumentation is utilised throughout the laboratory. Electronic and hydraulic devices developed especially for laboratory work are in common use, the accuracy of individual instruments being within $\pm 0{\cdot}1\%$.

In the measurement of head, the headrace and tailrace levels were transmitted to the measuring point in the control cabin by transducers, which relayed an air pressure equal to the submergence of two air probes. The number of revolutions of the turbine shaft over the test period were integrated by a Dekatron electronic counter, which was triggered every $\frac{1}{10}$ of one revolution by a transistor photocell. The measurement of torque was made by an automatic Prony dynamometer, the automatic feature being an electropneumatic servo control which adjusted the torque of the dynamometer so that any load applied to the end of the dynamometer arm was always maintained in exact balance.

To ensure that correct instrument calibration was maintained, frequent checks against known standards were made during the tests. Every precaution was taken during assembly to obtain correct alignment and eliminate undesirable friction. In the apparatus almost frictionless pulleys were used and the weight of the dynamometer was carried by three air-lubricated pads.

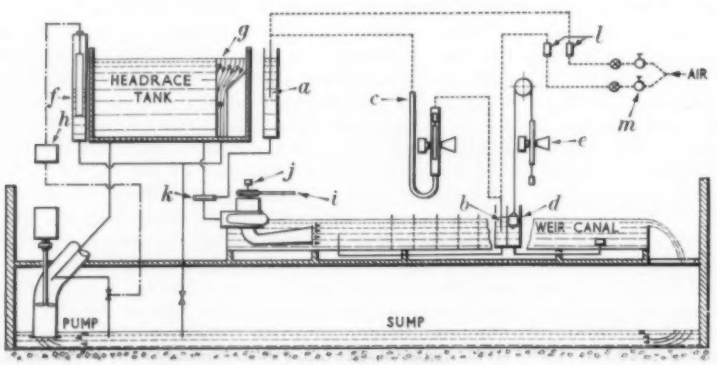
In the background of Fig. 3 can be seen one of the cavitation berths in the laboratory. As part of the Chute-des-Passes model-testing programme a 12-in diameter model turbine was installed in this berth, and a complete series of tests was carried out to prove that the prototype turbines would operate without undue cavitation pitting within the specified limits of power and headwater and tailwater levels. The cavitation factor under which the model was operated could be controlled on the model independently of other running conditions by regulating the absolute pressure in the closed hydraulic circuit. Thus, the complete range of field conditions could be simulated, and by using a Perspex draft-tube cone in combination with a stroboscopic light source it was possible to observe any tendency towards cavitation in the runner and draft tube. As a result of these observations it was possible to determine the location on the runner that was most prone to cavitation damage for certain load conditions, and to make provision accordingly for the application of limited stainless-steel protection on the full-scale turbines.

Model tests were not confined to the hydraulic design, and in their mechanical-testing laboratory at Whetstone, near Leicester, the designers were able to study a variety of stress and deflection problems; scaling and bearing problems were analysed with scale models and even full-size prototypes.

The mechanical construction of the Chute-des-Passes turbines follows well-established practice, and a high content of fabricated components was employed. Shipping clearances were sufficiently large to allow the design of the head cover, distributor ring, regulating ring and runner as single pieces. The spiral-casing stayring assembly was shipped in four quadrants.

The importance of the junction between the spiral-casing plate and lip of the stayring casting was recognised in the design stages, and special precautions were taken to reconcile the different allowable stress levels between the plate and casting. It was decided that the allowable tensile stress level of 10,000 lb/in² used in the general stayring-casting design could be increased to 12,500 lb/in² in the portion of the lip to which the spiral plates were welded, provided that a number of specified conditions were imposed controlling the weld and the quality of the casting material to be used. These conditions included a complete radiographic examination of the stayring lip at the foundry, and special impact tests of the materials. Also, the welded joint between stayring lip and spiral-casing plate was completed in the shop, subjected to 100% radiographic examination, and thermally stress relieved.

The scrollcase quarter sections were completely shop welded and stress relieved, and the bolted joints of the stayring quadrants were designed so that the bolts could be prestressed by heat tightening. Four radial spiral-casing joints were field welded and subjected to 100% radiographic inspection. The complete spiral-casing stayring assembly was pressure tested in the field to 600 lb/in². No difficulties were experi-



a. Headrace level transmitted to head manometer by air-pressure transducer
b. Tailrace-level air-pressure transducer
c. Optical projection manometer for total head
d. Weir-level float chamber
e. Optical projection of weir-level scale
f. Spillway-level chamber for vernier control of head
g. Extended weir to maintain constant headrace level
h. Pneumatic control for servo butterfly valve
i. Self-balancing Prony dynamometer supported on air bearings
j. Photoelectric pick-up for electronic revolution counter
k. Collector ring
l. Flow indicators
m. Pressure regulators

Fig. 4. Diagrammatic layout of model-turbine test berth

enced during either field welding or the subsequent tests.

The mild-steel runner, approximately 14 ft in diameter, was cast in one piece weighing approximately 35 tons. The areas of the runner most liable to damage from cavitation pitting were protected with stainless-steel overlay. To minimise the leakage past the runner, special replaceable double-toothed labyrinth seals were shrunk on the crown and skirt. These moving seals were arranged to run with very small clearances in matching labyrinth seals fixed to the head cover and pivot ring. The system of progressive contractions and expansions effectively reduces the leakage, and the small quantity passing the crown seal is drained through holes provided for this purpose in the runner crown. The runner is secured to the shaft with fitted bolts, which also transmit the torque.

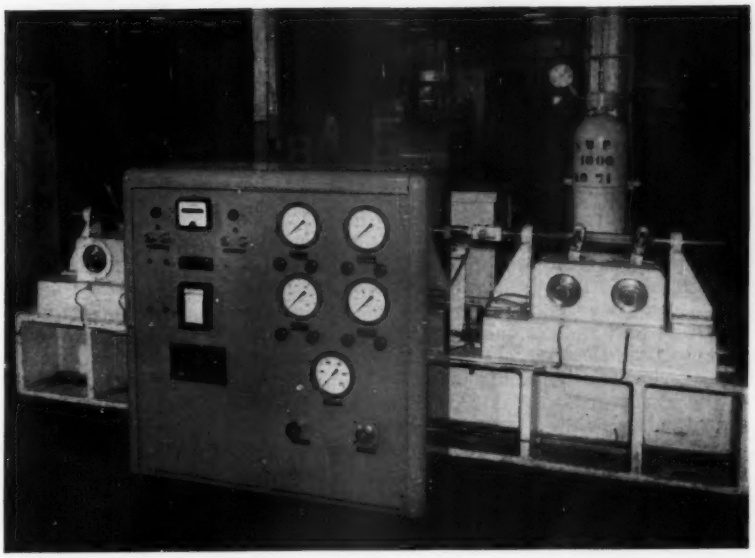


Fig. 5. Multiple slow-speed bearing-test facility with automatic torque-measurement recorder

The 42-in diameter main shaft is provided with a stainless-steel sleeve in the vicinity of the main shaft gland, and an integrally forged bearing collar for the self-lubricating bearing. As stated earlier, no generator shaft was used, and the turbine upper shaft flange was bolted directly to the generator thrust block, the outer periphery of which constitutes the generator guide bearing. Fitted bolts secure the thrust block to the turbine flange, and it was decided to align the thrust block and shaft in the shop, and to fit the bolts there.

The main shaft bearing is of the self-lubricated type with individually adjustable babbit-lined pads. Cooling is accomplished by passing water through a cavity in the bearing pad itself, and the bearing pads are all linked by a piping system. The main shaft gland is of the segmental carbon variety, and the carbon rings from a seal with a stainless-steel sleeve.

The guide vanes and regulating gear are protected from overloading by bronze shear pins in the linkage arrangement, and control is effected through the regulating ring from the governor-controlled servomotors. Both the head cover and the pivot ring were provided with stainless-steel liner plates in the vicinity of the guide vanes. The type 405 stainless steel used for the clad portion of the liner plates was also used to overlay the sealing surfaces at top and bottom of the cast-steel guide vanes. A Brinell hardness difference of approximately 100 points was maintained between the clad surface and the guide-vane overlay. Further stainless-steel protection was provided at the sealing surfaces located at the nose and tail of the guide vane and also on the bearing trunnions.

The general arrangement of the turbine and generator with the single shaft, and the location of all auxiliaries and components has resulted in an extremely compact and clean-cut turbine pit.

Electrohydraulic Governors

The advantages of electric governors in obtaining the best possible governor performance and flexibility of control desirable in large power-system operation are today generally acknowledged by the power-generating companies. The English Electric Co. Ltd. have been engaged since 1953 on the design and application study of various types of electric governors. Parallel development of magnetic-amplifier and transistor governors was also undertaken, and the experience gained was utilised in the design of the Chute-des-Passes electrohydraulic governors, which are magnetic-amplifier controlled. The order for these governors was obtained following a one-year demonstration of a magnetic-amplifier prototype in the Shipshaw power stations of the Aluminium Company's Saguenay system. During this demonstration period the reliability of the governor was assessed, and the operating personnel became familiar with its operation and performance. In addition to the usual governor acceptance tests of sensitivity, dead band, and speed variation with load change, a special test of system regulation was contrived by operating all other governors in the system against their gate limits, and allowing the electrohydraulic governor to regulate the system while 30-MW disturbances were created.

The electrohydraulic governor features, which permit joint operation, incremental speed droop, fringe control on tie lines (fast transient), and simple adjustment of governing parameters, are well known to control engineers. There are features of construction that are also worthy of attention. The most significant difference from mechanical governors is that there are no moving parts in the most sensitive section of the governor; thus, insensitiveness due to dead band and "stiction" in these sensitive parts is eliminated. This allows corrective action to be taken for frequency errors not detectable by mechanical means. Furthermore, the absence of moving parts means an absence of wear in the electric sensing head. The magnetic amplifier itself is a robust and durable piece of equip-

ment. The technique, controls and components used are similar to those that have been used successfully for steel-mill automation over the past ten years. The atmospheric conditions and vibration level of these mills are much worse than those occurring in generating stations.

The logical segregation of the mechanical and electrical sections of the governor leads to improved station layouts. The mechanical assembly, housed in the actuator cabinet, is located down on the turbine floor, permitting simplified piping and minimal lengths of return-motion cable. The control cubicle, on the other hand, is mounted with the electrical cubicle on the generator floor with the voltage-regulator and field-breaker cubicles. This division of the governor into electrical and mechanical assemblies is shown schematically in Fig. 6.

The electrical circuit is broken down into simple logical subassemblies, which are fitted to individual panels. These panels are then fitted to a standard 19-in rack in the cubicle, making a neat, convenient, and easy to maintain unit. Setting-up controls, to be clamped after commissioning, are fitted to the appropriate panels, and response controls such as droop, temporary droop strength, and time constant are brought out to a separate panel to permit adjustment while the unit is in operation.

The fact that both the power and the speed signal for the electric unit are obtained from a multi-pole 3-ph permanent-magnet generator coupled to the top of the generating units means that the unit is completely self contained, and, under emergency conditions, there is no dependence on external power for governing.

The master speed reference consists of a high-stability parallel-tuned circuit followed by a phase-sensitive rectifier unit. With the permanent-magnet generator running at the tuned circuit frequency, the phase-sensitive rectifier output is zero; if the frequency moves away from the resonance value, the output magnitude depends on the difference between the frequencies, whereas the polarity depends on whether the permanent-magnet-generator frequency is above or below the tuned circuit-resonance frequency.

The output is fed into a two-stage magnetic amplifier, the first stage being a push-pull mixing unit and the second a single-ended output unit. All control signals are fed into the first-stage unit. These may include the frequency described above, or load-control signals, tie-line signals, water-level control signals, or a combination of these and more.

Other panels of the assembly provide the necessary operating voltages, control and protection relays, and circuit-monitoring facilities. Protection is arranged to effect one of three actions, depending on the type of fault. These actions are:

(1) Complete shutdown.
(2) Shutdown to no-load gate.
(3) Application of gate lock.

The mechanical assembly contained in the actuator cabinet includes the electromechanical actuator, the pilot and main distributing valves, and the hand control gear, as well as the governor pumping set.

The electromechanical actuator is a moving-coil device giving a force of 24 lb/A, and arranged for a stroke of 0·5 in. Under zero-current conditions the armature is forced to the closing-side stop by a spring, whereas during normal governing the armature would be centred with a current of 0·5 A flowing. This safety feature ensures that, if the governor goes out of action, the turbine tends to shut down. A special gate lock is provided to check this shut-down tendency, and to hold a steady gate position in the case of certain detected governor faults.

The manual control of the governor is effected by means of a handwheel linked through the return-motion system to the pilot valve. This is shown diagrammatically in Fig. 7, which also indicates the arrangement of the 10-in main distributing valve and return motion linkages. The governor was designed to give opening and closing times of 5 sec, through much longer times have now been set as a result of detailed pipeline studies.

The advantages of locating the actuator itself near the turbine pit, which results in short lengths of governor piping, were fully realised at Chute-des-Passes, where a detailed study of alternative layouts was considered. The optimum arrangement was

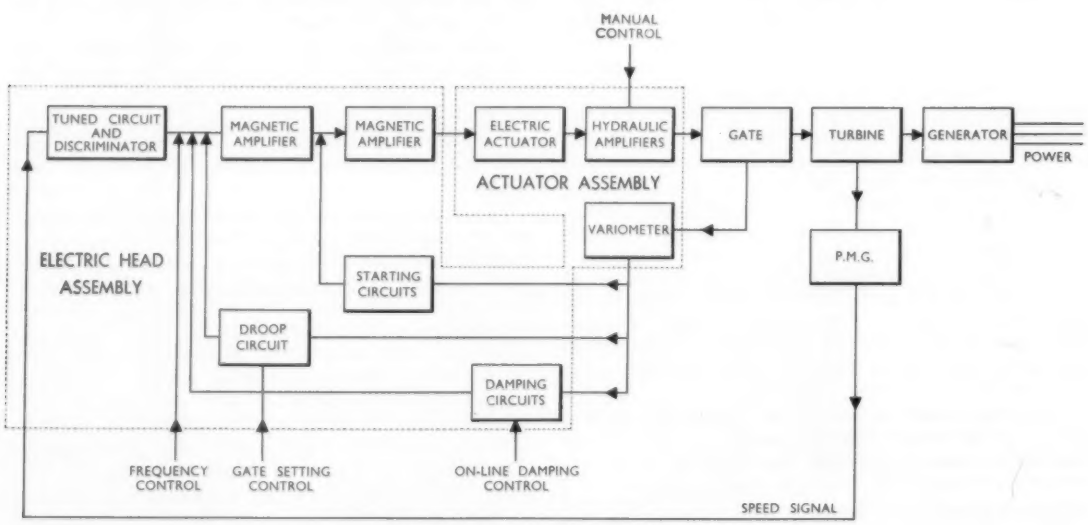


Fig. 6. Governor block diagram

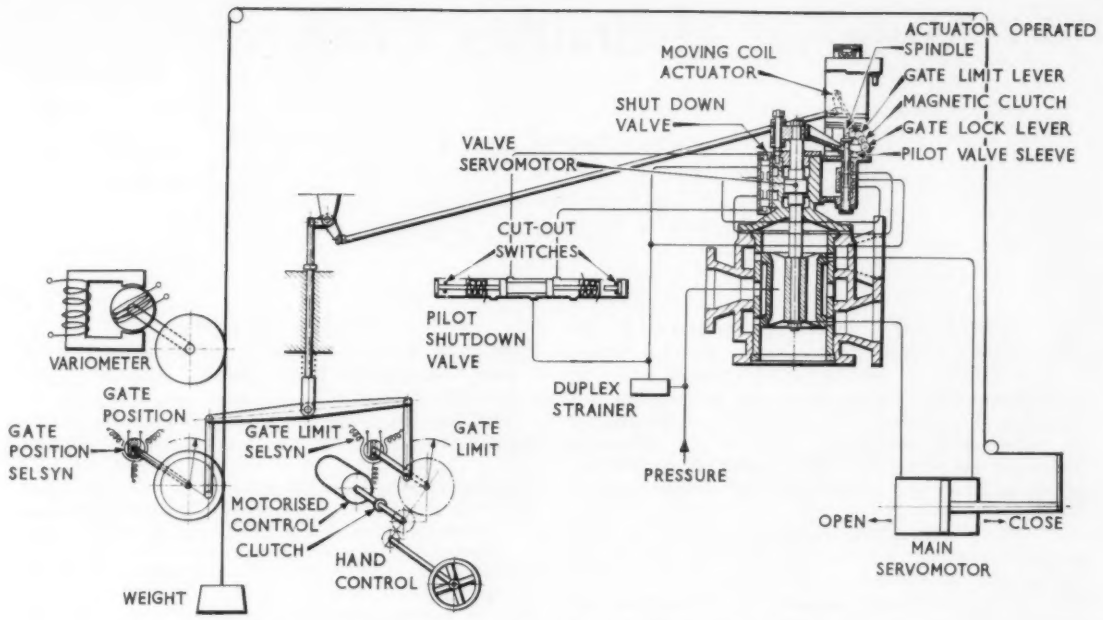


Fig. 7. Diagram of control for electrohydraulic governor

achieved with the pressure system on a unit basis, whereby each pumping set was provided with two vertically mounted 35-h.p. motor-driven pumps complete with relief, bypass, and safety valves, and was connected to a pressure accumulator immediately adjacent to the actuator cabinet. Other arrangements considered included the use of twin-cabinet actuators or, alternatively, an interconnection between all five units with a single larger pump in each unit. The unit system adopted, in addition to being the most straightforward, will also be simpler to service with the smaller pumps and motors.

With the unit system one of the two pumps was arranged to run continuously, the other only operating when actuated by a pressure switch during conditions of exceptional governor activity. To enable the service on the pumping equipment to be equalised, echelon control has been provided.

Two special points of note are the brushless variable transformer to provide the gate return-motion signals, and the gate lock to prevent the loss of generation previously mentioned. The gate lock can be selected either automatically or manually, and has an overriding automatic control to remove the lock on loss of electrical load.

Although an electric governor unit lends itself to automatic starting, starting at Chute-des-Passes is performed by hand control of the gates from the mechanical assembly, or by motorised control of the hand mechanism from the control room, the governor taking over as normal speed is reached.

Once operating speed is reached control of the governor is effected by means of a rotary control, fitted to the control-room desk and calibrated in terms of gate opening. This serves as a tuning control for synchronising, and as a calibrated loading control after synchronisation, and, thus, operators can set the control and leave the machine to pick up the required amount of load. This is of particular importance at Chute-des-Passes where a relatively large pipeline effect requires heavy governor damping with resulting slow response.

All the Chute-des-Passes governors are arranged for joint control, the transfer from separate to joint control being a simple switching operation by the shift operator at the control desk. The joint controls are grouped together on the operator's desk. The operation of the five units on joint control will give the equivalent of a single unit of 1,000,000-h.p. capacity, which can be used to regulate system frequency by operation at low droop or for tie-line fringe control. It should be added that on the line fringe control the joint machines require only one set of extra supervisory equipment, as opposed to a station without joint control, where a set of supervisory equipment would be required for every unit to operate on fringe control.

Acknowledgments

The manufacture and installation of the turbines were carried out by the John Inglis Company of Toronto, Canada. The author wishes to thank the Aluminium Company of Canada for their co-operation in providing some of the descriptive matter used in this text, H. G. Acres & Co. Ltd. for making available Figs. 1 and 2, and Mr. N. P. Percival, of the English Electric Company, for his assistance with the details of the electrohydraulic governor.

Pegasus 2 Computor System. Ferranti Limited have sent us a brochure describing the main features of the Pegasus 2 computor, both in its basic form and when used as a data-processing system. This is a serious technical publication and worthy of study by those concerned with the application of computers to engineering problems. The publication may be obtained from the London Computer Centre, 68–71 Newman Street, London, W.1.

Montreal Hydraulics Conference

A brief summary is given of papers of hydro-electric interest presented to a recent conference sponsored by the Engineering Institute of Canada and the American Society of Mechanical Engineers

A HYDRAULICS conference sponsored by the Engineering Institute of Canada and the American Society of Mechanical Engineers was held in Montreal from May 8–10. It was attended by 151 engineers, including 53 from the United States, and 36 papers were presented, 14 of which concerned hydro-electric matters. Brief summaries of these papers will be given under their appropriate subjects.

WATER HAMMER

Surges in Gate Air Vents. McCaig & Jonker (Canada) (61-HYD-2)

These authors examined air-vent phenomena following gate closure where back-surges can cause damage. The analysis determines minimum and maximum water levels in terms of closure rate and other parameters.

Surge-Chamber Phase Plane Equation. Marris (USA) (61-HYD-9)

In this paper the author introduced a new surge-chamber concept describing water-level motion utilising non-linear differential equation singularities for predicting performance. The simple surge-chamber phase plane solutions mapped in dimensionless terms confirm:

(i) Thoma's condition always gives instability.
(ii) Paynter's analogue-computer investigations for friction and inertial drainage on full-load acceptance.

PIPELINES

High-Head Pipeline Design. Smith (Canada) (61-EIC-10)

The author discussed pipeline design for different water-hammer and emergency conditions, turbines and climates, as shown in the table below.

Although low transition temperatures did not concern Kundah, cost, weldability and ductility without stress relieving were factors in choosing T1 steel for both installations. The comparative stresses (lb/in^2) are shown in the table overleaf.

PRIME MOVERS

High-Head Francis Turbines and Pressure Regulators, Mammoth Pool Project. Brown (USA) (61-HYD-21)

The features of these 360 r.p.m. Francis turbines rated at 88,000–98,000 h.p. and 950–1,032 ft head are:

(i) The 90/69-in butterfly valves with metallic sealing.
(ii) 60-in conical relief valves with correlated governor servomotor stroke and turbine characteristics, aeration and safety arrangements.
(iii) Water-depressing system for motoring with the inlet valve open.
(iv) Air admission to the throat at high gates and through the head cover at low gates.
(v) Runner removal via the draft-tube cone.
(vi) The 92·7% peak efficiency by the salt-velocity method and agreement with model tests.

Special attention was devoted to stayring and head-cover rigidity, guide-vane clearances, suspension and alignment and runner design in respect of:—

(a) Grinding blade entry and discharge edges to minimise shock.
(b) Penstock vibration elimination by combination of runner blades (15) and guide vanes (18) and their interspace clearances. Moreover, the blade tops were inclined to expose them gradually to the stationary parts, thus spreading pressure pulsations over longer periods.
(c) Seal location and clearances in terms of hydraulic thrust, leakage and cooling.
(d) Dynamic balance.

Pump Characteristics and Specific-Speed Effects on Hydraulic Transients. Donsky (USA) (61-HYD-3)

This author expanded the Karman-Knapp non-dimensional pump-test data for full and zero head in speed/flow co-ordinates into a family of curves using homologous laws for three specific speeds to derive characteristics in normal/reverse pump, turbine and energy-dissipation zones to ascertain water-hammer calculation errors with improper pump characteristics. It concludes that:

Location	Scheme	Turbine type	Gross head	Pipelines		Supports
				Diameter	Length	
			ft	in	ft	
Madras	Kundah	Impulse	1,177	63–51	3,240	Close spaced
			2,470	57–45	5,300	Masonry piers
Canada ...	Spray	Francis	900	96–84	1,600	Ring girders

Steel grade	A 285 C		T1	
Minimum yield	30,000		90,000	
Tensile	55,000		105,000	
Ratio yield/tensile	0·545		0·860	
Allowable stresses	17,000		40,000	
Margins on:	Safety factor	Stress	Safety factor	Stress
Yield	1·77	13,000	2·25	50,000
Ultimate	3·23	38,000	2·62	60,000

(i) Water-hammer estimates using approximate specific-speed characteristics are acceptable.
(ii) Radial pumps give greater down and upsurges than axial-flow pumps.
(iii) Valve-closure head rise depends (a) more on closing rate and flow-control time than on pump characteristics; (b) on reverse flow and is therefore greater with mixed- and axial-flow pumps.
(iv) High heads are produced by reverse flow (a) during valve closure; (b) when starting mixed- and axial-flow pumps.
(v) Power failure without valve closure gives (a) higher reverse speeds with axial-flow pumps; (b) maximum reverse speed in less wave-travel time for radial-flow pumps; (c) similar wave-travel times for slowing down to zero speed for all types.

The figures below are given in the paper:

Pump type	Specific speed (US gal)	Surge % rated head			
		Downward		Upward	
Radial	1,800	45	74	11	34
Mixed	7,600	39	70	0	0
Axial	13,500	31	60	4	0
Pipeline constant 2ρ		2	8	2	8

Pump and pipeline inertia $K.2L/a = 0{\cdot}1$

Development and Tests on Bulb Units. Cassaci, Duport (France) and Pariset (Canada) (61-EIC-13)

This paper outlined bulb-turbine development and the advantages of these machines in terms of specific speed, output and cavitation, for run-of-river and reversible tidal plants. Although much of the information is available through SHF (1958) and IAHR (1959) Conferences, it stressed the contribution of model tests to industrial realisation and gave data for the Cambeyrac, Argentat, Beaumont-Monteux and St. Malo units.

CAVITATION

Cavitation Tests for Accelerating-Flow Cascades. Numachi (Japan) (61-HYD-1)

The author investigated four theoretical designs experimentally for cavitation as a function of retarded inception, drag and lift coefficient. Further work is in progress.

Cavitation-Damage Mechanisms. Naude and Ellis (USA) (61-HYD-8)

Using perturbation theory and assuming constant pressure inside a symmetrical non-hemispherical cavitation bubble collapsing on a solid boundary, these authors confirmed, by high-speed photographs and damage on aluminium, that deformation occurs before attaining minimum volume and that cavities striking the boundary create higher pressures than those due to gas pressure. Damage is apparently influenced by cavity shape on impact with boundary, jet, velocity and tip radius, rather than collapse away from the boundary.

Cavitation-Erosion Prediction from Accelerated Tests. Hobbs (United Kingdom) (61-HYD-19)

This paper significantly pointed up future research to ascertain prototype damage, since there is some agreement between accelerated tests and field observations. Models might solve this problem despite unknown scaling laws, but distorted flows and pressures might be necessary because (i) Froude's Law gives low velocities where prototype cavitation occurs; (ii) at prototype head with reduced transit times, cavitation intensity and location are out of scale. Model tests with partially deaerated water under increased pressures are proposed with the affected parts in adequately strong erodible material, utilising the principle that because bubble collapse is at Δp^{-1} or v^{-1} it occurs at the same place.

Two rigs were constructed as follows:

(i) *Water Tunnel* with a 1 ft 6 in by 2 ft working section accommodating cylinders subjected to inlet and back pressures of 250 ft and 80 ft. Two observations are important: (a) air content and temperature; (b) blockage ratio for maximum erosion rates (80%).

(ii) *Variable-Speed Jet/Disc Impact Machine for Square Specimens*
Although cavitation is not simulated, tests show:—
(a) Correlation with water-tunnel, vibratory and constricted-tube devices.
(b) An "incubation" period and a limiting impact velocity related to fatigue strength.
(c) Weight loss proportional to jet area.
(d) Negligible corrosion because of short impact duration but increased erosion with salt solutions.
(e) Erosion independent of temperature and air content.
(f) Damage production 3,000 and 100 times faster than water tunnels and vibratory devices respectively.

High-Velocity Effects on Turbine Pitting. Lawton and Lester (Canada (61-EIC-2)

This paper presented 30 years' operational experience with a 110-ft head 45,000-h.p. Francis unit ($n_s = 67$) and a 164-in cast-steel runner for which the pitting rate ΔP is correlated with Δv^n and other data. Values of n are given in the following table:

Field		Laboratory	
Radioactive paint	Actual Isle Maligne	Aluminium plates	Mild-Steel discs
7·0	6·8	6·0	5·0

A cavitation threshold exists beyond which pitting accelerates and over-gate operation is undesirable, particularly with high-curvature blades.

ICE PROBLEMS

Research continues on ice problems where theory must be coupled with model tests and experience.

River/Ice-Sheet Heat Transfer. Baines (Canada) (61-EIC-4)

In this paper the author generalised on ice-sheet evolution. The numerical analysis based on two-dimensional water motion and heat-flow at the river/ice-cover interface reveals that:

(i) The temperature is almost constant.
(ii) Discharge variations may change the lateral shape.
(iii) Flow capacity decreases 13·3% approximating De Bellmond's measured 36% head-loss increase.
(iv) Local thickness control is possible by air bubbles or water jets, inducing shear.

The difficulties and inconsistencies with observations are emphasised.

Formation and Evolution of Ice Covers on Rivers. Pariset and Hausser (Canada) (61-EIC-6)

This extension of the La Salle work analyses ice-cover development via basic hydraulic and mechanical laws, and utilises St. Lawrence River and Beauharnois Canal measurements. Water velocity is the classifying parameter, and by demonstrating that cover progression by ice-floe juxtaposition is one phase of a general mechanism, establishes the limits of thickening or melting by heat transfer via air/ice/water interfaces and snow cover. Relationships are developed for the upstream ice thickness and external forces due to thrust, flow and wind shear and bank reaction for narrow and wide covers. Ice, being plastic, thickens by deformation or crushing if stressed beyond the breaking limit, giving the "shove" phenomenon. The theory explains the action of booms, which relieve ice-cover stresses. Model tests require two materials (wood and plastics) for non-submersion and cover-stress problems.

GENERAL

Two papers bordering on mathematical philosophy and engineering economics deserve mention.

Interpretation of Experimental Data. Jones (Canada) (61-EIC-12)

The quest for accuracy is described as an engineering challenge, and with hydraulic examples of economic significance the paper dwells on measurements, function-fitting, interdependence, interpretation and dimensional analysis.

Measures of Value and Statistical Models. Clough (Canada) (61-EIC-5)

In decisions regarding flood-control or water-conservation schemes the key is cost and benefit scales. Two appraisal problems are explored, where even approximate analysis involves (i) defining acceptable value scales for tangibles and intangibles; (ii) a statistical description of flood damage; and (iii) weighting of intangibles where market or price structures do not exist or reflect social values.

An adaptation of Churchman & Ackoff's method of estimating values based on expressed preference is proposed for comparing competing multi-purpose projects. For the statistical model, potential, peak, seasonal and sequential floods lead to Monte Carlo simulation for damage assessment. These are claimed to give realistic valuations where political or local economic considerations are important, but nevertheless assume acceptance by people unaccustomed to mathematical aids to judgment.

Kompass Register. A new British company, Kompass Register Limited, of Therese House, 29/30 Glasshouse Yard, Aldersgate Street, London, E.C.1, is now undertaking the compilation and publication of a large register that will contain a detailed list of products and manufacturers in all sections of British industry. The index and the products and services classification will be in five European languages, and are likely to give information on some 25,000 firms. Similar registers for the products and companies of Switzerland, Spain, Sweden and Denmark are already available, and registers other than the United Kingdom one are also in the course of preparation.

New Automation Company Formed. The General Electric Company Limited, of England, and Thompson Ramo Wooldridge Incorporated, of Los Angeles, USA, have formed a new British company to market industrial process control systems in Great Britain, the European Free Trade Area and the British Commonwealth.

Canadian Electrical-Power Industry

THE Thirteenth British Electrical Power Convention was held at Eastbourne from June 12–15, and had as its theme: "Electricity in Prosperity and Welfare of the Nation." Four papers were presented by well-known authors, of which "The Electricity Power Industry in Canada" by A. E. Grauer, B.A., Ph.D., LL.D., was probably of the most direct interest to hydro-electric engineers.

The paper by Dr. Grauer, who is chairman of the British Columbia Electric Co. Ltd., dealt with a large subject, and the author treated it logically and succinctly. It is perhaps not generally realised that Canada, despite her relatively small population of some 18 million persons, stands second only in total electrical output to the USA and the USSR, and is roughly on a par with the United Kingdom. On an output *per capita* basis, Canada is led only by Norway, another highly developed hydro country. Dr. Grauer briefly traced the rapid development of the Canadian electrical-power industry, and then described the present situation, the main feature of which is the growth of individual utilities, which are founded essentially on the provincial structure of the country.

Canada's power requirements for the future, and the means of financing the anticipated growth, were considered, and Dr. Grauer showed that these requirements may continue to grow at an average rate of more than 6% per annum, and necessitate the installation of between about 40,000 and more than 60,000 MW of new generating capacity by 1980. Such an expansion would require an expenditure of several thousands of millions of dollars, but confidence is expressed in the ability to raise these funds, both from Canadian and overseas investors.

The potential resources for increased power production and their relative importance were carefully considered, and it was evident that hydro power still has a major part to play, with Quebec and British Columbia having the largest undeveloped resources. In common with most other countries, the estimate of exploitable water-power potential has been raised several times, and Dr. Grauer now suggests a value of the order of 70,000–80,000 MW, which compares with the present installed plant capacity of some 20,000 MW. In some parts of Canada, however, the economic hydro resources have now been fully utilised, and there is likely to be a large increase in thermal installations, particularly in Ontario. The introduction of nuclear power was also discussed, and once again there appear to be possibilities in Ontario, where nuclear power may come earlier than in other areas of Canada.

The cost of electricity production was covered in some detail by Dr. Grauer, and he showed that the generally world-wide trend towards a narrowing of the gap between thermal and hydro generation costs also applies in Canada at the present time. However, he felt that, although hydro-electric energy might rise in cost from about five mills/kWh to some six mills in the early 1970s, thermally produced energy is not likely to cost less than about six to seven mills/kWh.

A number of problems of great importance were described, including that of long-distance transmission and the question of a national grid for Canada. The author considered that the case for the grid had yet to be made, and the cost is likely to be a major deterrent. The problems of fish protection were also briefly discussed. The paper concluded that Canada would continue to have an international electrical cost advantage for some decades, due in some measure to its low-cost hydro resources, and that thermal power would have an increasing role to play in conjunction with the hydro-electric developments.

B.H.R.A. Open Days

The British Hydromechanics Research Association recently held their annual Open Days at the Harlow laboratory, and the usual interesting display of models that we have come to expect was provided. Although much of the B.H.R.A. work is outside our particular field, a number of investigations are concerned either with hydro-electric schemes or with problems of common interest to the hydro-electric and the water-supply engineer.

One of the most interesting studies from our point of view is, unfortunately, only in the model-construction stage at the moment. In order to assist the hydrological study of the Kaduna River in Nigeria, where it is proposed to build a hydro station, some rapids have been trimmed by blasting to form a rough weir for gauging the dry-weather flow. A scale model is now being constructed to obtain an approximate calibration of the weir. The model will be contained in a 3-ft deep brickwork tank, which is at present 24 ft by 24 ft, but which can be extended to a length of 70 ft.

Another large model is that for the spillway and stilling basin for Sasuma dam in Kenya. The model has been constructed to a 1 : 30 scale, and is intended for the investigation of the proposed design, which is for a maximum discharge of 16,000 cusecs. Particular attention is to be paid to conditions at the junction of the spillway and natural water course, where adverse site conditions have restricted the stilling-basin design.

It is clear that much useful work is being done in the applied fluid-mechanics field, and many examples were shown of such studies as pump-sump and turbine-intake design, with particular reference to the formation of vortices, cavitation in control valves, pressure surges in pipes, and the hydraulic problems involved in pipe layouts for pump-testing circuits. The use of air models in closed-conduit flow systems continues to be a feature of the laboratory's work.

Dominion Engineering Co. Ltd. This company's power crane and shovel division have sent us a pamphlet in which their large range of plant is depicted pictorially.

Pressure Grouting. This is the title of an interesting and useful publication by George Wimpey & Co. Ltd., Hammersmith Grove, London, W.6. The brochure describes, with the aid of actual examples, the various applications of pressure grouting in foundation and repair work.

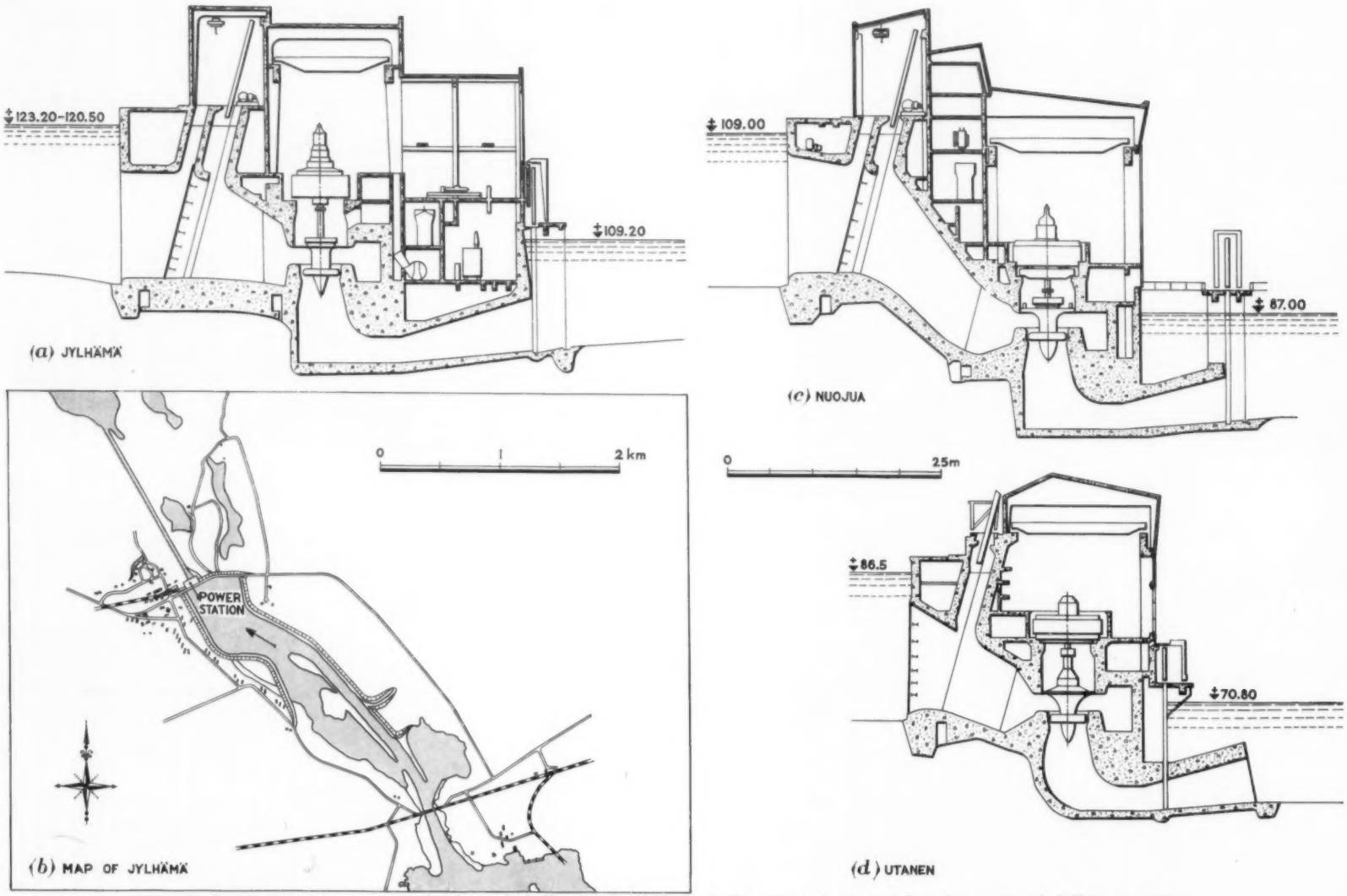


Fig. 18. Sections to the same scale through Jylhämä, Nuojua and Utanen stations and location map of Jylhämä station

Fig. 19. Site of Jylhämä station before development, looking towards Lake Oulu. Aerial photograph by Veljekset Karhumäki Oy

Power from the Oulu

In this article we describe the stations on the upper section of the main Oulu watercourse. The Oulu—one of the most important rivers in the north of Finland—will have an aggregate installed capacity of 530 MW and an average annual output of 2,750 GWh

PART THREE

IT now remains to describe the stations on the main watercourse of the Oulu, which extends from Lake Oulu to the Gulf of Bothnia. Reference to the map of the main watercourse given in Fig. 2 of our June issue will assist in following this description.

It will be remembered that the lowermost station—Merikoski—belongs to the city of Oulu, but that the other stations have been built by Oulujoki Oy. The first station to be built—and the largest—was Pyhäkoski, which was completed in 1948, after which the construction group concerned finished Pälli station in 1954 and Montta in 1957. A second construction group, operating farther upstream, built Jylhämä station in 1951, Nuojua in 1954 and Utanen in 1957.

In last month's article relating to the stations on the Emä we pointed out how design techniques had developed in planning successive stations. Buildings and civil-engineering structures became simpler, more compact, and therefore cheaper, and the height of the generating sets was reduced by such devices as placing the thrust bearing on the turbine cover. A similar trend of development can be discerned in the case of the plants on the main watercourse, and it is to assist the reader in this respect that we have repeated the various dates of construction. Indeed, the stations now being considered illustrate the point more completely, for Pyhäkoski and Jylhämä—the first two stations to be built—have indoor transformer and high-voltage switchgear halls, whereas the later stations have outdoor transformers and switchyards.

A difference in planning between the Emä and Oulu stations which will be immediately evident is that the Emä series are single-machine installations whereas each of the stations on the Oulu has three machines. The choice of three machines per station on the main watercourse was influenced in the first place by the design of Pyhäkoski station, where the 40 MW, 150 cu. m. per sec., 32 m. head machine was as large a unit as was feasible in the circumstances and where the total flow called for three such machines. Moreover, the stations on the main watercourse are in constant service, and the use of three

Fig. 20. Interior of Jylhämä power station, showing the machine hall and the adjacent switchgear annexe

machines enables maintenance to be carried out with the minimum loss of water and of output.

On the other hand, the flow on the Emä can be easily handled by a single machine; furthermore, the stations on this watercourse are peak-load installations planned to be run 3,500–4,500 hours per annum, and there is ample time to carry out all necessary maintenance, and the excellent regulation prevents loss of water.

Having drawn attention to these interesting factors we are now free to describe the stations in their natural order from upstream to downstream.

Jylhämä Station

As explained in our first article, Jylhämä forms the regulating station for Lake Oulu, and to obtain the necessary storage without excessive flooding the natural outlet of the lake had to be lowered by 1·5 m. As the terrain in the vicinity is very flat (see Fig. 19) a great deal of heavy excavation was needed. A channel 2·5 km. long was cut from Lake Oulu to the site of the power station, involving the removal of 40,000 cu. m of rock and 45,000 cu. m. of earth, and to form a forebay nearly 4 km. of lateral dykes, 6–7 m. high. had to be built. Below the power station a tailrace

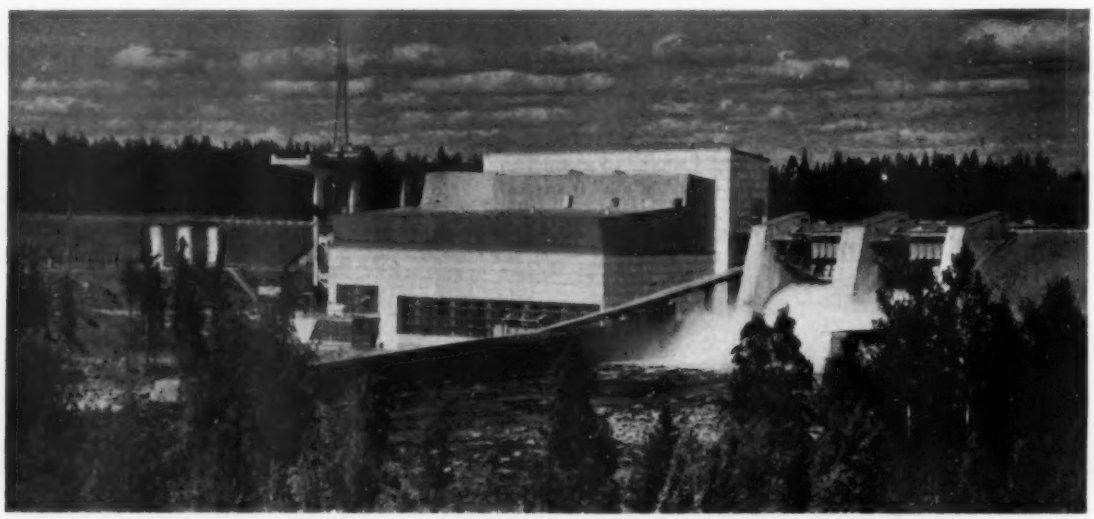


Fig. 21. Downstream view of Nuojua power station

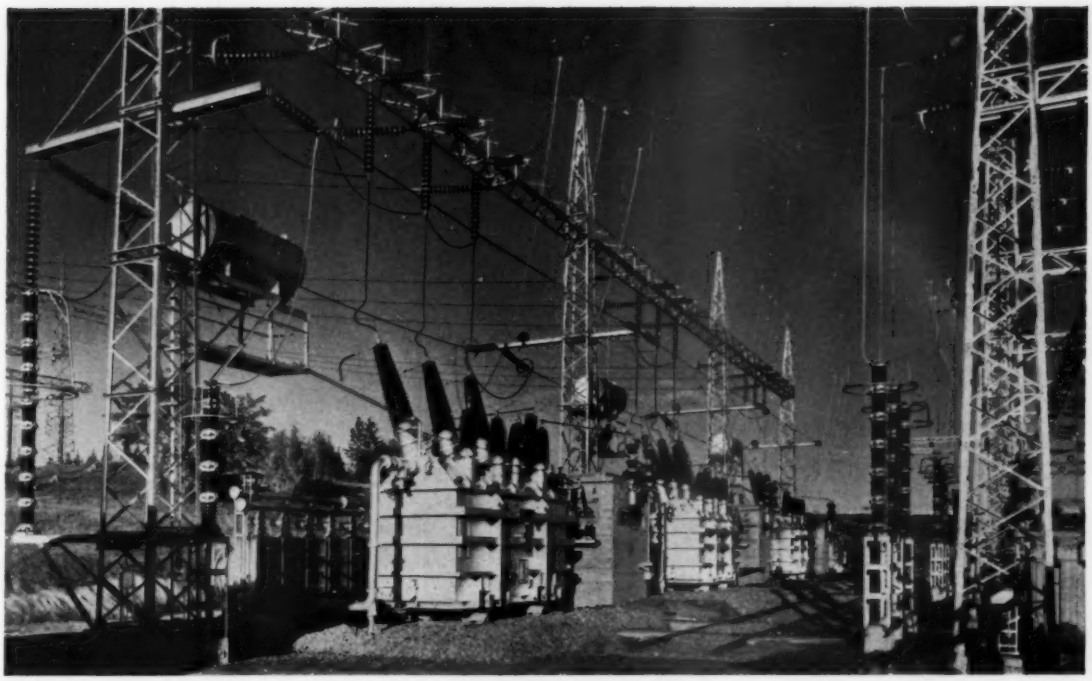


Fig. 22. Nuojua switchyard and main transformers. This is a nodal point in the transmission system

channel, 1·6 km. long, 25 m. wide and 16 m. deep, had to be blasted almost completely out of the rock. Altogether, about 700,000 cu. m. of earth had to be excavated and a similar quantity of rock blasted. Up to 12 excavators and 200 trucks were in use at any one time, and the station and dam site was served by a 6 ton cableway having a span of 500 m. The location map, Fig. 18, gives some idea of the extent of the works.

Jylhämä also formed the main construction centre for the upper section of the river, and a concrete batching plant, repair shop, stores, and living accommodation for more than 1,000 workers were located here.

The spillway is immediately to the right of the power station and has two openings, each closed by a Tampella tainter gate 14 m. wide by 7·95 m. high. A log chute is situated between the spillway and the power station.

The section through the power station given in Fig. 18 reveals the characteristics of the earlier design approach. A separate hall has been built to house and handle the inlet sluice gates, the generating sets are comparatively tall, the draft-tube sluice gates are at the

Fig. 23. The control room at Nuojua station

Fig. 24. Downstream view of Utanen station, spillway and tailrace

mouths of the tubes, and a transformer switchgear block has been built over the draft tubes. These features have been progressively modified in succeeding designs.

The machine hall (Fig. 20) is 66 m. long and is equipped with a 125 ton Kone crane. It houses three 17 MW vertical Kaplan sets, comprising Tampella turbines operating on a head range of 11 to 14 m. and coupled to Oerlikon 10·5 kV generators, the power from which is stepped up by ACEC transformers. The average annual output is 220 GWh.

Nuojua Station

Several favourable factors combined to make the construction cost of Nuojua station exceptionally low. In the first place, as the site is only 5 km. below Jylhämä, it was unnecessary to move the Jylhämä construction camp, which, with its offices, stores, workmen's accommodation, concrete batching plant and repair shops, became the construction headquarters for Nuojua. All that was necessary was to move the portable equipment and to organise transport for the requisite labour force and stores. In this connection, road and rail access were established in 1949–50. Then again, the site was a favourable one, as the only major civil-engineering task was to cut a tailrace channel, the material from which formed the dam. Here, too,

Fig. 25. General view of Utanen machine hall

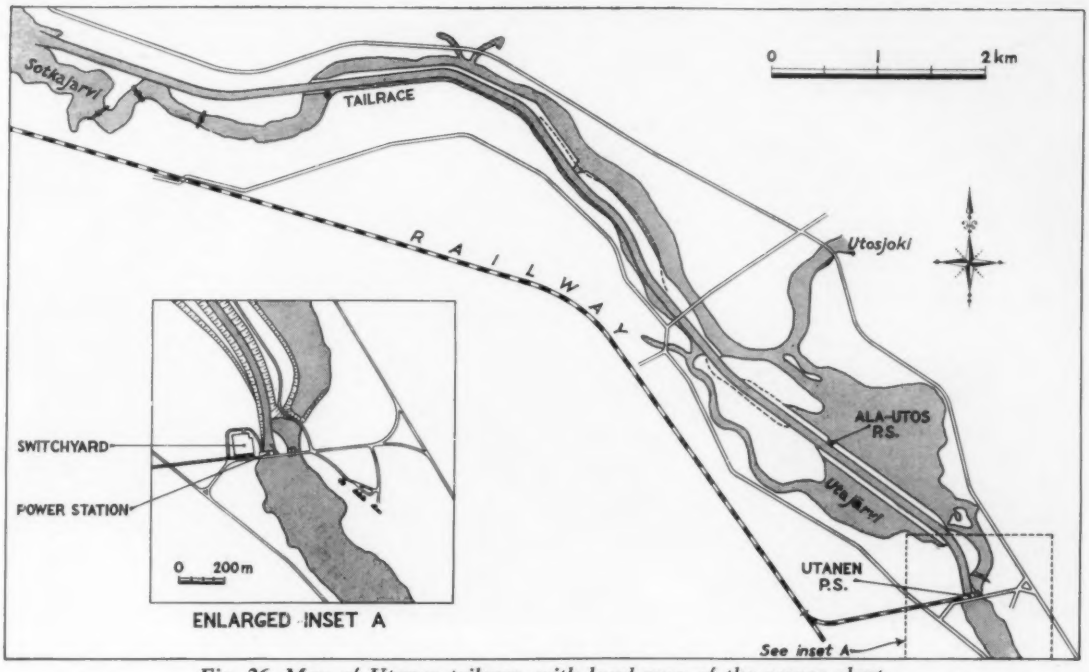


Fig. 26. Map of Utanen tailrace, with local map of the power plant

the river banks are high, so that little land was lost by flooding. The capacity of the station also reacted favourably on the unit cost; its installed capacity of 80 MW is second only to that of Pyhäkoski, and its average annual production is 400 GWh. These factors have made it possible to build the station for a cost of 76,000 FM. (£85) per kW installed.

The power plant is located above the Nuojua rapids, and the tailrace was cut through a rocky promontory forming the right bank of the rapids. This tailrace, which leads to Nuojua pond below the rapids, called for the excavation of 230,000 cu. m. of earth and 275,000 cu. m. of rock. Much of this material was used to build the dam which seals off the river bed and is 20 m. high.

The log chute and spillway are immediately on the left of the power house. Two openings in the spillway are regulated by 14 m. × 6·5 m. Tampella tainter gates, and discharge to a stilling basin and thence to the old river bed.

The outdoor switchyard lies to the right of the power house immediately downstream of the embankment.

An unusual means has been adopted for handling the heavy equipment required for the switchyard and power house. A railway track is laid across the dam, and immediately to the right of the power house a reinforced-concrete crane gantry has been built, extending over the railway track on the dam on the one side and over the station yard at switchyard level on the other. Heavy equipment can thus be transferred direct from railway wagon or road lorry to switchyard level or vice versa. This gantry, which can be seen to the left of Fig. 21, can also be used to lift timber from the forebay on to railway wagons.

The station framework is of reinforced concrete and is clothed with insulated concrete wall panels. Nuojua is the operational centre for the upper three stations on the main watercourse, and due attention has been paid to heat insulation to ensure the comfort of the staff. Larger office premises are provided than are available at the other two stations in this group, and the living quarters are ample and are beautifully situated on the shore of Nuojua pond.

Three 27 MW generating sets are installed, consisting of Tampella vertical Kaplan turbines operating under a head of 22 m. and driving AEG generators at 136·5 r.p.m. A section through the station is given in Fig. 18. The average annual output of the station is 400 GWh.

As befits an operational centre, Nuojua forms a nodal point in the electrical transmission network. The Emä River power is brought down by a 220 kV line from Seitenoikea, and two 220 kV transmission lines leave Nuojua—one to the south of Finland and the other to Pyhäkoski. Power from Jylhämä is received at 110 kV.

The main transformers consist of three three-phase three-winding units, each rated at 64/32/32 MVA at 231/115·5/10·5 kV and supplied by AEG. The 110 kV circuit breakers and the 220 kV transformer circuit breakers are Oerlikon minimum-oil units, the 220 kV line breakers being of AEG manufacture and of the air-blast type.

Utanen Station

Utanen was the last station on the main watercourse to be completed, and it is interesting to compare its cross section with that of Jylhämä (both given in Fig. 18), which was the first of the upstream group and is somewhat similar in capacity and head. The mean head at Utanen is 15·7 m., the installed capacity 55 MW, and the average annual output 280 GWh.

This station is particularly interesting from the civil-engineering standpoint, as it concentrates the head over a 35 km. stretch of rapids between Nuojua

Fig. 27. Aerial view of Utanen tailrace cut through the river bed

and Pälli, comprising Kurenkoski and Ahmaskoski rapids above the station site and Utakoski and Sotkakoski below it. At first it was proposed to build two stations on this stretch, but a single station was found to be the more economic proposition, particularly as the total head averages only 15·7 m.

To develop this head it was necessary to cut a tailrace channel 27 m. wide at bottom, 14 m. deep below water surface, and nearly 12 km. long, from the station to Lake Sotka. This tailrace, indeed, is an outstanding achievement, for it had to cross Lake Uta with its water surface 6·5 m. below that of the lake, and subsequently followed the old river bed—again at a lower level—for most of the way to Lake Sotka. A map of the tailrace, together with a site plan of the station, is given in Fig. 26, and an aerial view of that part of the tailrace where it passes through the existing river bed is reproduced in Fig. 27.

Over its course through the lake and along the river bed the tailrace is flanked on each side by a dyke Fig. 27) which normally seals off the lake and river waters but can be overtopped if the lake level should rise unduly. Lake Uta not only forms part of the main Oulu watercourse but is also fed by a small tributary, the Utos, flowing in from the north-east. To harness this flow, and also to make use of the difference of level between the lake and the tailrace, a small power station of 550 kW capacity, known as Ala-Utos station, has been built into the north-eastern dyke where it crosses Lake Uta. The position of this station is indicated in the map, Fig. 26. It is equipped with a Tampella turbine, a Strömberg generator and transformer, and a Raahe spillway gate.

Owing to the large scale on which earth and rock work had to be carried out a considerable amount of construction machinery was required. At the tailrace site nine excavators were employed, all fitted with buckets of more than 2 cu. m. capacity. The largest was a dragline with a 60 m. boom and a 6 cu. m. bucket. Over ten bulldozers and some thirty 20 ton trucks were used to transport spoil. Rock blasting was carried out by vertical drilling, mainly with the aid of wagon drills installed on crawler tractors, using 4 in. and 2½ in. bits. Excavation of the tailrace entailed the removal of 3·2 million cu. m. of earth and more than 3·8 million cu. m. of rock.

After the tailrace had been finished, the rapids above the station were dredged. The Kurenkoski rapids were cleared in 1955–56, entailing the removal of 170,000 cu. m. of material, and in 1957 some 145,000 cu. m. of material was removed from the Ahmaskoski rapids.

The power house is built on bedrock on the south-east bank of the river. To the right of it is a log chute and a length of plain concrete gravity dam, beyond which is the spillway, having two $14 \times 6{\cdot}5$ m. openings controlled by Tampella tainter gates. The spillway discharges into the old river bed, but the bed is sealed off by a dyke a little way downstream and the discharge is diverted into the tailrace. This can be seen clearly in the inset in Fig. 26.

The station building has a reinforced-concrete framework and is clad with prefabricated lightweight concrete panels; the exterior is covered with corrugated aluminium. On the interior the walls are left in natural concrete, rendering painting unnecessary. A decorative touch is imparted to the machine hall by the treatment of the busbars, which are carried along the upstream wall in three horizontal passageways, one above the other, protected by metal grilles.

Within the machine hall, to be seen in Fig. 25, are three 18 MW generating units consisting of Tampella vertical Kaplan turbines driving Strömberg generators which are connected to AEG transformers. The station is served by a 125/30 ton Kone crane.

(To be continued)

IEC Water-Turbine Committee

A brief report is given of the Fifth Plenary Session of Technical Committee No. 4 (Hydraulic Turbines) of the International Electrotechnical Commission held recently at Interlaken

THE Fifth Plenary Session of the International Electrotechnical Commission's Committee No. 4 covering hydraulic turbines, which met in Interlaken from June 26–28, was attended by 47 delegates under the chairmanship of Prof. L. J. Hooper (USA). The representation comprised: United Kingdom, 4; Norway, Sweden and Finland, 11; Belgium, France, Switzerland and Italy, 13; Austria and Germany, 4; USSR, Czechoslovakia, Hungary and Yugoslavia, 4; USA, 3; China and Japan, 8.

The previous session of IEC/TC4 in Madrid in July, 1959*, delegated major items of business to "Working Groups" for completion in accordance with the Committee's broad requirements. Progress reports received on these tasks are summarised below:—

Field Test Code for Hydraulic Turbines. This is circulating under the Six Months' Rule, and comments from National Committees are due in Geneva on October 31, 1961. An "Editorial Group" was constituted to agree the text of the English and French editions, which may be published about mid 1962 and a second edition will be put in hand shortly afterwards. This draft Code was favourably received in the USSR.

Model-Turbine Test Code. Drafting was delayed by the Field Test Code, on which it is to some extent dependent. A preliminary version, however, was distributed to the Editorial Group and it is anticipated that a second draft may be completed by November, 1961.

Field Test Code for Storage Pumps. The draft issued to National Committees received considerable attention and the Working Group had to codify commentaries from 11 countries for presentation to the Committee. This was taken as a measure of interest rather than criticism, since few questions of principle were involved. The amendments agreed were referred to an Editorial Group with the target for submitting the revised draft to Geneva fixed for Spring, 1962, preparatory to circulation under the Six Months' Rule.

Test Code for Hydraulic-Turbine Governors. As anticipated, this was not an easy task, but a partial draft attracted constructive comments from Japan, Canada, Russia, Sweden, and notably from France, which formed the basis for the new document referred to the Committee. This embraced new techniques and modern regulation and servo-mechanism concepts, but excluded machine and load characteristics, which will undoubtedly bring added complexity to the work assigned to Working Group "R." The new document was referred back for completion before circulation to National Committees for comment and subsequent revision preparatory to consideration next session. This Code, almost without precedent in the field of standardisation, poses complex problems and it will be interesting to see how the next draft stands up to the scrutiny of specialist designing, manufacturing, shop and site-testing engineers.

Working Group "U" on Units. This report was not unexpectedly given an indifferent reception by the less academically minded Committee members accustomed to traditional systems, which are not necessarily homogeneous. Apparently the meeting did not observe that the Working Group on the Governor Code had adopted the metre-kilogram-second system. The question of units and nomenclature vis-a-vis hydraulic machinery proper, the use of non-dimensional relationships in lieu of absolute values, and co-ordination with IFAC symbols may not be easily resolved.

It transpired, however, that IEC have accepted the new system, and discussion centred on the most expedient method of covering a transition period so that First Edition Codes will not be delayed in publication and so that the relationships with existing units of measurement will be readily understood. The impact of the new system on current textbooks, data and practical test procedures may have important consequences, and although there may be some resistance to its application by conservative hydraulic engineers, it will no doubt be readily adopted by younger engineers whose scientific education will enable them to realise its advantages in turbine, pump and governor development and testing.

Other Business

Discussions under this heading produced some interesting proposals, notably by the USSR delegate, from which it might be inferred that Soviet hydroelectric engineers are experiencing difficulties in plant operation, presumably with the large units which have been reported under construction. The Committee received them sympathetically and noted the co-operative spirit coupled with them, but because many aspects involved research outside IEC/TC4's scope and more appropriate to IAHR, full effect could not be given to these suggestions.

SOVIET PROPOSALS FOR NEW YORK

Hydro-Electric Unit Vibration. Enquiries will be made through National Committees for information which should enable the Committee to decide whether a Working Group could produce a Test Code on which performance standards could be based.

Model and Prototype Cavitation. This question is not yet solved technically, and although the basic proposal was not adopted a Study Group was set up to define "critical sigma" and the methods of presenting cavitation results.

Plant Operation and Maintenance. This was reviewed at Madrid (1959) and reconsideration resulted in USSR and Sweden being invited to report back on

* See WATER POWER, August 1959, p. 314.

the possibilities of a Code to cover this topic.

OTHER QUESTIONS

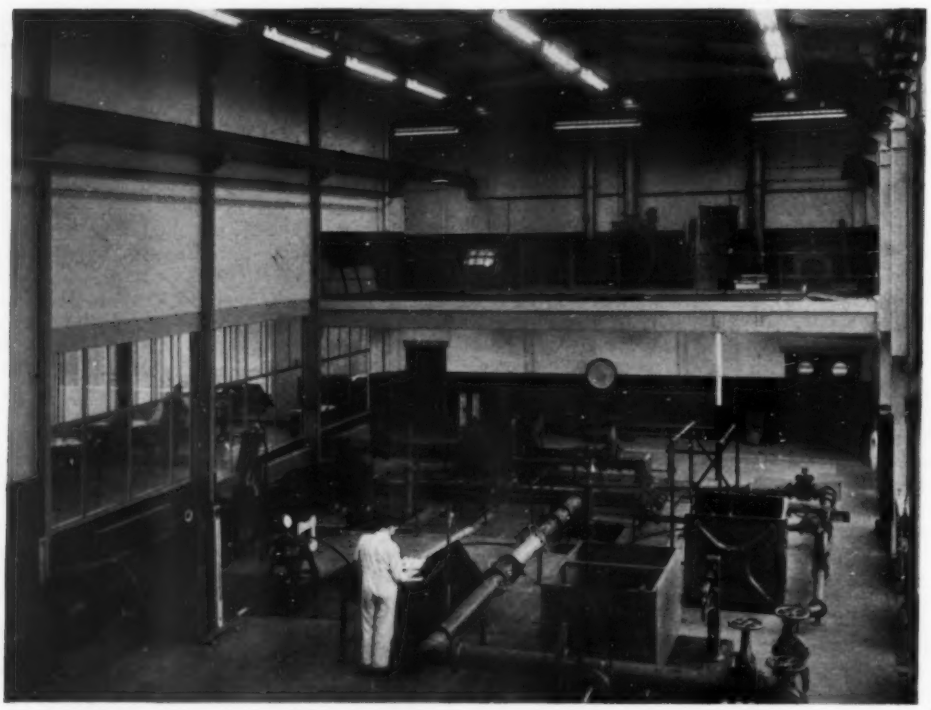
Co-ordination With Other International Organisations. Now that the Field Test Code for Hydraulic Turbines is nearing publication, to be followed by one for Storage Pumps and later by others for Model Tests and Governors, the need for liaison with other bodies such as the International Standards Organisation (ISO), the International Federation on Automatic Controls (IFAC), and probably within IEC, is becoming apparent and methods of effecting co-ordination were reviewed.

Storage-Pump Model Test Code. A Working Group was appointed to report on the need for such a standard, possibly as a supplement to that on Model Turbines.

The Committee adjourned after agreeing that the next conference should be in Venice in 1963 unless an earlier meeting was deemed necessary. This promises to be interesting, since many topics, old and new, will be on the agenda.

On the whole, all three meetings proved effective, and a well-directed, friendly and constructive spirit prevailed throughout. With work on prototype turbines and storage pumps approaching completion in the technical sense, new business such as model tests, turbine governors and regulation, and units, introducing more modern concepts than hitherto, will have to be examined.

A New Hydraulics Laboratory

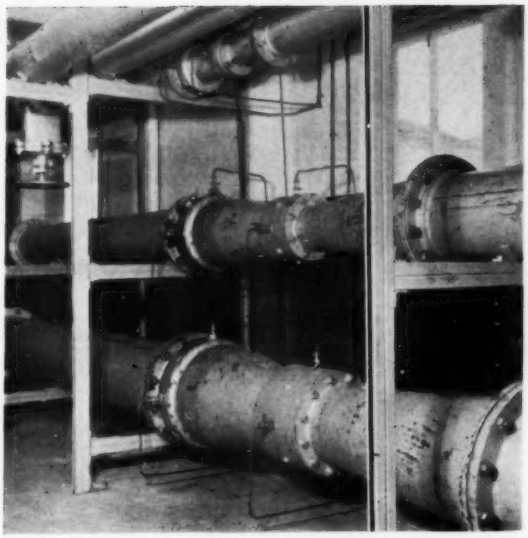


General internal view of Glenfield & Kennedy laboratory looking north

On June 8, a new hydraulics laboratory owned by the Glenfield group of companies, and operated by Glenfield & Kennedy Limited, of Kilmarnock, Scotland, was officially commissioned. The laboratory, which is sited close to the Kilmarnock works, has been designed to perform the basic functions of testing established products to determine soundness of design and to aid in further development, and of providing fundamental data for the development of new designs.

With these objectives in mind, past experience showed that the main requirements for the laboratory were likely to be that pressure heads and flow ranges had to be extensive and flexible, working space had to be sufficient to allow flexibility of layout, and the test equipment had to be of a high standard of accuracy. Glenfield & Kennedy feel that the laboratory adequately meets these and other requirements, and that ample facilities have been provided for the testing and proving of a wide range of hydraulic equipment.

The laboratory is essentially a steel-framed brick



Venturi meter bank

building of pleasing appearance, with portals supporting an aluminium-decking clad roof. The building is 128 ft long by 42 ft wide, and consists principally of a two-storey main block, a three-storey tower at the northern end, and a two-storey office annexe on the western side. The annexe includes modern drawing-office facilities and a reference library.

The major portion of the ground floor is taken up by the reinforced-concrete main storage tank, which has a working capacity of 72,000 gal. Passages containing fixed piping, Venturi meters, and pipe connections to the working floor above, are situated on either side of the tank. At the northern end of the tank, and on the ground floor of the tower, are the pumping sets; at the opposite end of the tank, and on the same level, are a delivery bay, circuit-breaker, boiler, and transformer rooms, and a filtration plant.

The working floor, which forms the roof of the main tank and ground-floor side passages, has clear dimensions of 75 ft by 39 ft. It is cambered, with lateral drainage channels, which discharge to a drainage sump, and access to the main tank is provided. The whole length of the main building is served by a 5-ton travelling gantry crane.

A mezzanine floor is sited over the pump room, and extends over part of the working floor. It has an area of 53 ft by 31 ft, and is intended for small-scale experiments and investigations involving working models. At the top of the tower, and above the mezzanine floor, is located the constant-head tank and an aerodynamics laboratory. The tank has a capacity of 14,000 gal, and provides a constant head above working floor level of 36 ft, with a maximum variation of $\frac{3}{8}$ in.

The fixed pipelines of the laboratory connect the pumps to the constant-head tank, and the pumps and overhead tank to the working floor. The principal feature of the layout is that, with the exception of the vertical risers, the pipes are all below working-floor level. They are of bitumen-coated steel, and vary in diameter from 6 to 18 in. The pipe arrangement is such that the pumps may be connected either singly, in series, or in parallel to either the constant-head tank or the working floor. In either case, the water can be passed through any one of three Venturi meters, and also through pressure-reducing valves, if necessary.

Four main horizontal-spindle centrifugal pumping sets have been provided, consisting of a Harland Spiroglide multi-stage pump with a duty of one cusec at 400 ft head and 1,470 r.p.m., two Harland Uniglide single-stage split-casing pumps with duties of 10 cusecs at 35 ft head and 975 r.p.m., and one Uniglide with a duty of 2·5 cusecs at 42 ft head and 970 r.p.m. The pumps are driven by slipring induction motors operating from a 415 V, 3-ph, 50 c.p.s. supply.

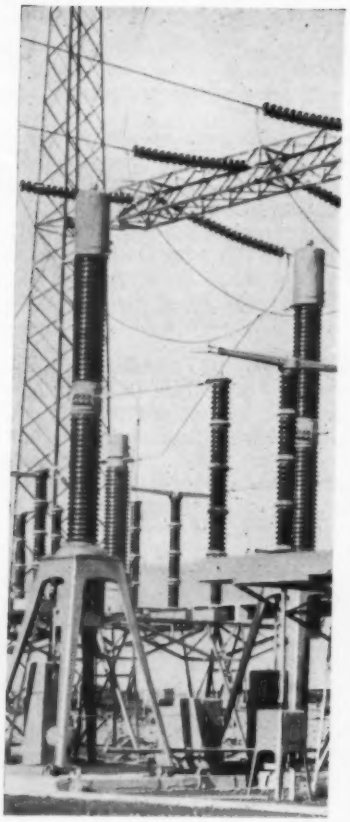
In order to maintain the laboratory water in a clean condition, it is abstracted from the northern end of the main tank and passed through filtration plant, whence it is returned to the tank through its southern inlet. During the working day, the water is pumped continuously at the rate of 5,000 gal/h through a Stellar filter, and thus the total capacity of the tank is filtered in a period of 16 hours.

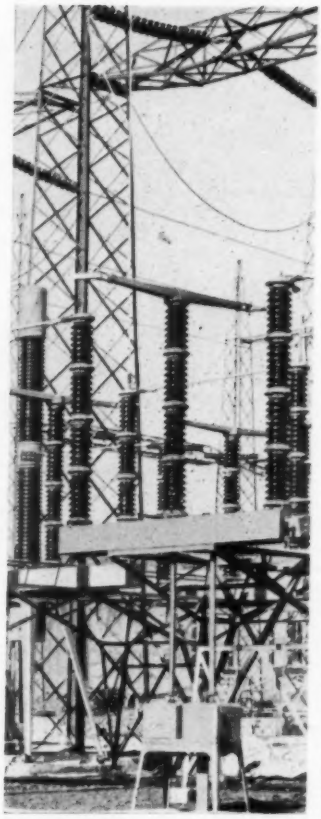
The wide range of flows and pressures provided by the installations is illustrated by the following requirements that can be fulfilled by the 10-cusec units:

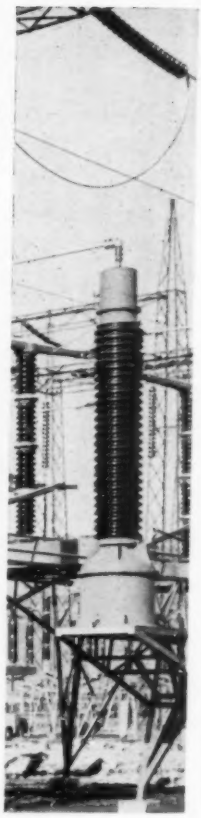
(a) One or both pumps can deliver, through the overhead tank, any flow up to 20 cusecs at a constant head of 35 ft.
(b) Either pump can deliver less than 10 cusecs at heads up to 65 ft.
(c) The two pumps in parallel can deliver less than 20 cusecs at pressures up to 65 ft.
(d) By connecting the delivery branch of one pump to the overhead tank, and the tank to the suction of the second pump, flows up to 10 cusecs at heads up to 100 ft can be obtained.
(e) By connecting the delivery branch of one pump directly to the suction branch of the other, the pumping head can be doubled.

Flow measurement is made by either standard Venturi meters, measurement of weight per unit time, or orifice plates. The Venturi meters, which are normally used, are of 6, 12, and 18 in diameters, corresponding to flow ranges of 0·6–1·8, 1·3–6·0, and 4·0–20·0 cusecs respectively. Accurate measurement of very small flows can be made by means of a portable tank and weighbridge. To control the flows,

General view of pump room







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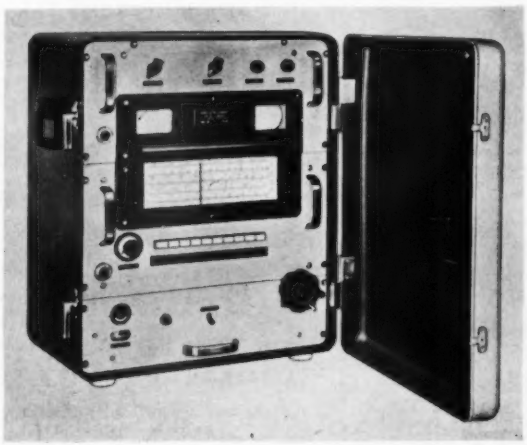
two main types of control valve are employed in the laboratory, both of which are designed to ensure freedom from fluctuations of flow and pressure. The first type is the pot valve, and the other a spear-type valve used with the weighbridge.

The laboratory building was designed and constructed by the Kelvin Construction Co. Ltd., Glasgow, and the equipment was supplied by some 16 specialist manufacturers.

Device for the Non-Destructive Measurement of Elastic Properties

An aid to quality-determination in structural materials by non-destructive means has been introduced into the United Kingdom by Aveley Electric Limited, of Ayron Road, South Ockendon, Essex. The E-G meter manufactured by Kretz is designed to make rapid and repetitive measurements of the dynamic modulus of elasticity and the torsional modulus of solids such as metal, concrete, rock, plastics, wood, coal, and ceramics. This wide range of applications by the E-G meter is said to be obtained by a simple and rapid operation, and the sharp discrimination of the instrument is claimed to give repeatable measurements within 0·5%.

The dials are directly calibrated in tons/cm² and lbs/in². The use of five calibration units and the push-button selection of ranges are stated greatly to speed up the testing of a large number of samples. The 10-in long slide-rule dial carries a calibrated scale for the common materials, and extra scales for special material. The accuracy of the instrument is ensured by a built-in quartz-crystal-controlled oscillator, which provides check points on the dial. The equipment, which is portable, is self calibrating and is fitted with a pulse-transmitting test-probe and a mounted adjustable receiving probe to ensure accurate application to the test sample.



Heavy-Current Switchgear for Ffestiniog

In the Ffestiniog pumped-storage scheme the power plant consists of four 93-MVA generator-motor sets, each circuit being controlled by a 3,000-A oil circuit breaker, and the whole system by two 16-kV 1,500-MVA switchboards. This equipment is being supplied by the General Electric Co. Ltd.

Each switchboard consists of three panels, the two end units containing the 3,000-A circuit breakers, and the central section the heavy-current busbar connections between the 6,000-A and 3,000-A busbars. Busbars run the length of each switchboard, and tee-off connections go from each centre panel to two 16/290-kV 160-MV main transformers. The overall dimensions of each switchboard are 23 ft long by 11 ft 6 in deep by 12 ft 6 in high.

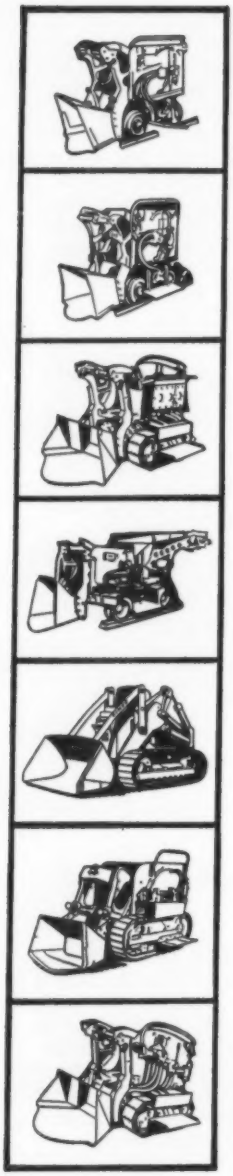
A feature of the design is the considerable use of non-magnetic steel for the busbar chambers and of non-magnetic alloy for the framework and panels. This is a necessary adjunct of heavy-current gear, and is designed to keep the eddy-current losses, and consequently heating, to a minimum.

Condenser-type tubular busbars, which also form part of the G.E.C. contract, are used inside the building to link each main transformer with its switchboard. These busbars have an outside diameter of 8½ in and an internal diameter of 7½ in, and are mechanically protected on the outside by a layer of binding wire, which also acts as an earthing sheath. The busbars are mounted at 3 ft 3 in centres and are brought from each switchboard through the switchhouse wall to the transformers. Two jointing chambers, consisting of one oil-filled unit inside the switch house and an air-insulated unit outside, split each busbar into three sections. Flexible laminations in these jointing chambers allow for busbar expansion, and silver-plated joints prevent undue temperature rise. An earth bar is taken from each oil-filled busbar jointing chamber inside the switch house to the neutral point of the appropriate main transformer.

Connections between the 6,000-A and 3,000-A busbars are made inside an oil-filled chamber contained in the centre panel. Copper-strip connections are taken from the main 6,000-A busbars to spherical clamping arrangements bolted to the 3,000-A tubular busbars. From each clamping point a tapping is also taken to supply the 1,000-kVA station transformer. This tapping is connected to a long Bakelised paper bushing extending from the busbar chamber to a cable box at the rear of the unit. At the cable box end this bushing passes through a small chamber whence a connection is taken from each phase for a voltage transformer situated at the back of the panel. This 3-ph class B voltage transformer is used for synchronising purposes, and is rated at 200 VA per phase, isolation being carried out by a hand racking mechanism.

Each bushing also carries a bar-primary-type current transformer used in the station transformer protective scheme.

Each end panel of both switchboards houses a



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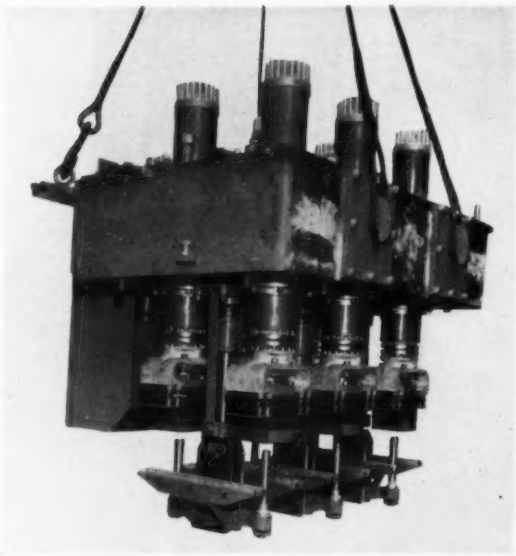

One of the 1,500-MVA, 3,000-A oil circuit breakers for Ffestiniog

3,000-A 16-kV 1,500-MVA double-break oil circuit breaker, protective and metering current transformers, and a voltage transformer. Each circuit breaker is fitted with a solenoid-operated closing mechanism, which can be controlled remotely or from the switchboard itself. Raising and lowering of a circuit breaker for maintenance is carried out electrically by means of a simple form of lifting screw-hoist gear driven by a motor, which is vertically mounted at the top front of the panel.

Some of the protective current transformers associated with the generator-motors and main transformers have to be located on the feeder side of the 3,000-A circuit breakers. This has necessitated the provision of current-transformer chambers at the top rear of the 3,000-A panels. Separate earthing arrangements are provided for each circuit breaker and a full complement of interlocks is incorporated.

The main protection fitted to each generator-motor is a conventional circulating-current system, which requires two sets of three current transformers for each generator-motor. One of these sets is located inside the switchgear on the busbar side of the 3,000-A circuit breaker. Adjacent to these bar-primary-type current transformers is another set supplying a three-pole overcurrent relay, and, also, a single-pole earth-fault relay is connected in the neutral lead. Duo-bias protection is fitted to both generator-transformers. Each can be supplied by two generator-motors through the 3,000-A circuit breakers. It is therefore necessary to mount bar-primary-type current transformers on the feeder side of the circuit breakers and, for each switchboard, to connect them to a common set of interposing transformers located in the centre panel.

Any fault arising on the 16-kV busbar system immediately causes the tripping of both 3,000-A circuit breakers, and also of the 275-kV switchgear at the Trawsfynydd switching station.

The Blaenau Ffestiniog pumped-storage scheme was described in the Leading Editorial of the February issue of WATER POWER, following a paper presented by H. Headland to the Institution of Mechanical Engineers in London.

Silicone Resin for Asbestos-Cement Board

Cement-bonded asbestos board is widely used as a non-inflammable and heat-resistant electrical insulating material. In many applications, however, its high rate of water absorption with consequent loss of insulating properties is said to be a serious limitation, which can be overcome by impregnation of the board with a suitable silicone resin.

Midland Silicones Limited, of 68 Knightsbridge, London, S.W.1, have recently developed a new resin especially for impregnating asbestos board. This is DP 2728, which is supplied as a low-viscosity solution in toluene. Asbestos-cement board impregnated with DP 2728 is said to retain good electrical-insulating properties for very long periods, even in conditions of 100% relative humidity, whereas under similar conditions untreated board will soon show a serious loss of insulation resistance.

Silicone-impregnated asbestos board is often used for arc chutes in air-break switchgear, or as spacing insulation on electrical apparatus under certain conditions. It is stated to be particularly useful in the construction of dry-type transformers, and as a substitute for paper-phenolic boards where heat or flame resistance is needed.

Improved Pocket Penetrometer

The soil penetrometer has become a useful tool for the rapid estimation of the unconfined compressive strength of some cohesive soils in the field, and an improved model has recently been announced by TESTlab Corporation of 3398 N. Milwaukee, Chicago 41, Illinois, U.S.A. This is a pocket model, which operates by pushing a stainless-steel rod into the soil until it penetrates to a depth of $\frac{1}{4}$ in. As the piston penetrates the soil, a pressure is exerted on a calibrated spring, and, simultaneously, an indicator sleeve moves along a calibrated scale. The sleeve remains in position to facilitate reading, and has to to reset manually. The penetrometer, which is said to be easily dismantled for maintenance purposes, is very light and has a length of only $6\frac{1}{2}$ in. The scale is graduated to read directly in tons/ft² or kg/cm².

Modified AWCO Line Tap

The Aluminium Wire & Cable Co. Ltd., of 2, St. James's Square, London, S.W.1, have modified their aluminium-alloy ALCU Universal Bi-Metal line tap, by replacing the castings of the earlier design by forgings. It is stated that, as a result, a lower-cost tap of better appearance and improved performance has been provided. The new ALCU tap is available in two sizes, ALCU-10 and ALCU-20, and covers the same total range of conductor sizes as before, i.e., 0·240–0·558 in diameter aluminium mains conductors and 0·092–0·300 in diameter copper service conductors. The three sizes of soft aluminium tubes used over the service conductors are unchanged.

One of the 180,000 kVA 13·2/120 kV three phase 60 cycles transformers being lowered into the hold of the ship at Manchester, England en route for Lewiston.

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Abstracts from the World Technical Press

Moselle Development

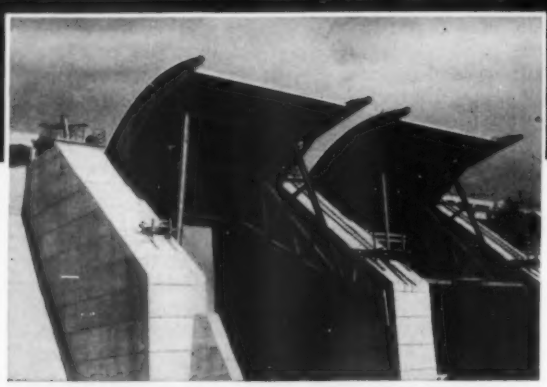
This development is the outcome of the treaty signed by France, Germany and Luxemburg on October 29, 1956, for the purpose of ensuring the navigability of the Thionville-Coblenz stretch of the river for 1,500-ton boats. The works now in progress, as well as those to be instituted later, are described, and the article also lists the improvements of navigation conditions that will result when the development of this major tributary of the Rhine is fully completed. The hydro-electric projects that are to utilise the ten storage stages contemplated on German and Luxemburg territory are reviewed, and a more detailed description of the Trèves installations is given. In addition to comprehensive navigation facilities, this stage will include a power station equipped with four tubular turbines of the Kaplan type with double governing systems, designed for a discharge of 380 m³/sec, and an aggregate capacity of 18 MW; the anticipated average yearly production will be approximately 80 million kWh. The spillway block, consisting of three 40-m wide sluices and 3·5-m wide piers, is separated from the power station by a pier and a fish pass extending downstream. The height of all these structures has been kept as low as possible so as to blend with the surrounding landscape. Mention is also made of the Vianden development (WATER POWER, March 1960, p. 88), which is actually part of the Moselle scheme, as it is being constructed on the Our River, a sub-tributary of the Moselle. The two paragraphs concluding the article are devoted to the operation of the Moselle series of plants by co-ordinated releases, similar to the method applied to the Isar, Lech and Neckar systems in Germany, and to the pumped-storage schemes that are to be implemented upon completion of the Moselle development. One of these schemes, the Lower Moselle project, which is to be constructed between Müden-Lemen and Coblenz, is to have an installation of four 90-MW sets, operating under an average head of 300 m with a maximum turbine discharge of 150 m³ and a pumped output of 80 m³/sec. (Dr. Ing. Benno Kretzschmar, *La Houille Blanche*, November 1960, p. 690, 14 pp., 10 ff.)

Present Trends in Penstock Design

The great progress achieved in a few decades up to 1949 in the design of large penstocks supplying powerful high-head turbines is reviewed. Following this period, the advance up to 1956 was less spectacular but was nevertheless marked by the execution of large-scale projects, such as the Pragnères scheme, which involved the commissioning of overpressured self-hooped penstocks. At the present moment, an even more ambitious scheme, Roselend, is coming into operation. These recent developments, as well as other major projects now at the planning stage, have led to a revision of the articles and conditions of existing specifications, especially those applying to operating dependability. With the help of new computation methods derived from the latest advance in mathematics, it is now possible to determine valid coefficients of reliability, on the basis of which the numerous large penstocks that have been designed and installed can be operated with complete confidence. These methods, when applied to new developments, have enabled optimum factors of reliability to be determined, which fully meet the conditions under which the plants are established and operated. In addition to increased operating reliability, the quality of the constructional material involved has also been substantially raised by improved manufacturing processes, especially welding, and applying in factories and workshops modern means of control, such as ultrasonic testing equipment, which has now been perfected to a high degree of efficiency. Present trends also aim at determining a maximum value for the ratio of elastic limit to breaking strength, and at testing in the manufacturer's shop the penstock sections at such a pressure that the corresponding stress is definitely lower than the elastic limit; this procedure, however, must be supported by a genuine and tangible coefficient of reliability corresponding to at least twice the working pressure. Other more recent trends endeavour to obtain absolute protection from any outside influences, including sabotage; this problem can be solved in various ways, according to the conditions confronting the designers in any particular development. At last, it has now become the rule to consider from the economic viewpoint the penstock and its associated civil-engineering works as a single unit. The extent of this civil-engineering work is a direct function of the structure of the penstock, and the solution involving the lowest expenditure in penstocks does not necessarily result in the cheapest layout. Heat-treated and tempered steels with a very high elastic limit are in increasing demand for manufacturing welded penstocks, and their use proves particularly advantageous in double-wall self-hooped penstocks, such as those selected for the stretch of the Roselend penstocks laid in a steel-lined tunnel. (G. Ferrand, *La Houille Blanche*, Vol. 15, No. 5, September–October 1960, p. 601, 16 pp., 9 ff.)

Nelson River Development

This paper, presented at the 74th Annual General Meeting of the Engineering Institute of Canada, deals especially with the dam and dykes of the Kelsey generating station, the first hydro-electric development on the Nelson River, which flows into Hudson Bay 425 miles due north of Winnipeg. In this instance, economic and schedule considerations dictated that a rockfill dam should be constructed on bedrock across the river, and that dykes should be built on unfrozen and permanently frozen foundations. For the design of the 120-ft high, 955-ft long rockfill structure, which has a sloping core, extensive laboratory testing was performed on the highly plastic core material. Construction delays and inclement weather conditions necessitated slight design modification, and it was also necessary to complete construction of the core within heated enclosures placed upon the dam. The dykes on permanently frozen ground were constructed in winter of sand brought to the site by rail. It is expected that the foundations will thaw gradually due to heat from the reservoir. Sand drains have been provided in the foundations to facilitate drainage and



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Photos 1 and 2
7 spillway tainter gates 12 x 12 m for dam flood control

Photo 3
Wye pipe for hydraulic power conduit
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Outlet opening 4240, pressure 7.6 atm. g
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accelerate consolidation during thawing. Virtually no precedent was available, and design had to be based qualitatively upon theoretical heat-transfer and consolidation considerations. The latter involved testing, under carefully controlled conditions, samples of frozen and thawed foundation material. Sensitive temperature and settlement measurement devices have been installed in the foundations to check performance and design assumptions. These observations will serve to give warning of any impending troubles, and will provide valuable information for the design of future water-impounding structures on permanently frozen foundations. Considerable settlement is expected and periodical or continuing maintenance may be necessary on these dykes. Construction, which began in June 1957, was to be substantially completed during the summer of 1960. The drainage area of this development to the site is 389,000 sq miles, and the reservoir area is 200 sq miles. The sluiceway, which is equipped with nine gates 40 ft by 43 ft 6 in of the fixed-roller crest type, is designed for a discharge of 250,000 cusecs. The power station will have five generating units with an aggregate initial capacity of 210,000 h.p., and provision will be made for a possible ultimate capacity of 420,000 h.p. (D. H. MacDonald, R. A. Pillman and H. R. Cooper, *The Engineering Journal*, Vol. 43, No. 10, October 1960, p. 87, 10 pp., 10 ff.)

Riprap Placing at Oahe Dam

An efficient and ingenious method has been developed by the contractor for the Stage 7 earthwork of Oahe dam for placing riprap on the upstream face of the 90-million cu-yard embankment. The work involves placing 728,000 tons of riprap (top 3-ft layer of 4-in to 3-ft boulders), 95,000 tons of spalls (12-in middle layer of 2-in to 6-in spalls), and 90,000 tons of filter blanket (12-in layer of filter gravel placed directly on the rolled-earth embankment). A fleet of 25 end-dumping trucks, with an average capacity of 12 tons, transports the riprap from deposits within a 20-mile radius of the dam. At the dam site, the trucks are lowered backwards a maximum of 550 ft down the face of the embankment on 600 ft of $\frac{3}{4}$-in wire rope controlled by a power winch mounted on the rear of a heavy-duty crawler tractor. The slope is 1 in 3, and the trucks are kept running in gear at all times to avoid rutting or otherwise displacing the spalls or filter blanket. The riprap is placed in two areas along the 9,300-ft embankment, each truck dumping its load as near as possible to the final position, and final placing is effected by cranes and $\frac{3}{4}$-cu-yard buckets. Both cranes operate on steel platforms supported horizontally on the embankment slope; there are three of these platforms to each crane, so that they can be leapfrogged and the cranes can work continuously. (*Engineering News-Record*, Vol. 166, No. 6, February 9, 1961, p. 45, 2 ff.)

An Improved Technique of Reservoir Desilting

The technique described in this article is less of a novelty than an improvement of procedures previously applied to the Oued-Alfa, near Orleansville, and other Algerian reservoirs (WATER POWER, May 1956, pp. 163 and 174), and subsequently in the USA to the Cat Creek reservoir (WATER POWER, September 1958, p. 361). The main advantage of the technique is that it can be applied without having to empty, even partly, the storage reservoir, the dam being holed under full working load. The method consists essentially in drilling from the downstream face of the dam almost horizontal holes, which open out on the upstream face below the upper level of the silt layer, that is to say well below storage level. The points at which the holes reach the upstream face are protected by a diving bell acting as a watertight working chamber. This implies the initial excavating of a pit in the silt to enable the diving bell to be fitted on to the upstream face of the dam, against which it is tightly held by the pressure of the water. Since absolute watertightness is precluded by the fairly uneven surface of the face, the water in the reservoir is artificially frozen at the joint, so as to form a perfectly impervious seal. The handling of the diving bell is controlled from a special gantry moving on the crest of the dam. An access shaft laid against the face of the dam, and equipped with a lift, connects the platform of the gantry with the top of the working chamber. All the operations of the bell and the ancillary equipment are controlled from a master panel mounted in the control cabin of the gantry. All drilled holes are steel lined, and each is fitted with two special gates of very strong construction made of small-size components, which can be easily assembled or dismantled in the narrow space available. Four desilting holes have been drilled and fully equipped at the Oued-Fodda dam. They have operated several times and proved highly satisfactory. The very thick silt is expelled in compact jets, with very little oscillation, from a height of 30 m into the valley. The whole equipment is kept permanently on the dam, so as to be put into operation at once in the case of a failure of one of the upstream gates or whenever maintenance work is required. (Roger Jarniac, *Travaux*, Vol. 44, No. 314, December 1960, p. 695, 14 pp., 24 ff.)

NOTE: *La Technique de l'Eau*, Vol. 14, No. 168, December 15, 1960, pp. 43–44, contains a short account of a lecture and film on the above subject presented by M. J. Thévenin at a meeting convened by Institut Technique du Bâtiment et des Travaux Publics and Société des Ingénieurs Civils de France.

Mettur Tunnel Hydro-Electric Scheme

Upon completion of its first stage, this scheme—the seventh project undertaken by the Madras Electricity Department—will add 100 MW of installed capacity to the Madras grid, and will utilise the irrigation water released from the Mettur dam reservoir to develop power for about seven months in the year. At present, the average irrigation demand is about four times the average discharge of the four 10-MW generating units of the existing Mettur plant. The new development is to draw the full irrigation discharge through a 500-ft long channel cut on the foreshore of the Mettur reservoir; the channel leads to the inlet of a concrete-lined pressure tunnel 45 ft in diameter and about 1,350 ft long. A surge shaft, about 200 ft deep, separates the tunnel from the four 21 ft 6 in diameter penstocks. Initially, the power station will house two vertical Francis turbines, each coupled to a 50-MW generator with step-up transformers and associated switchgear. A transmission system of 110-kV and 230-kV lines will link the new power station with the existing grid. The Mettur Tunnel scheme, so named to distinguish it from the old Met-

tur development, has been included by the Government of India among other developments earmarked for Russian aid, and the construction site was visited in May 1960 by a Soviet delegation. The two 50-MW units are to be delivered within two years of the signing of the contract with Machinoexport Corporation, Moscow. (V. P. Appadurai, *Indian Journal of Power and River Valley Development*, Vol. X, No. 11, November 1960, pp. 5 to 8, 1 f.)

Surge-Tank Stability

In this paper the author attempts to solve the problem of the hydraulic stability of surge tanks in the various intricate applications of this type encountered in practice. The problems considered include cases in which the power system comprises a canal fed by an additional source of supply, as well as surge tanks fed by two reservoirs. The fundamental theory of surge tanks forms the basis of the paper. (P. Kaichev, *La Houille Blanche*, Vol. 15, No. 6, November 1960, p. 678, 12 pp., 7 ff.)

NOTE: Other papers of water-power interest included in the above-mentioned journal are as follows: "Sudden Opening or Closing of an Outlet Valve in a Pipeline," by T. Hayatashi and G. Ransford, p. 657; "Direct Solution for Determining the Diameter of a Rough Pipe in Turbulent Flow," by N. Rajaratnam, p. 714; "Limits of Applicability of the Hazen-Williams Formula," by M. H. Diskin, p. 720. These three articles are printed in French and English.

The New Schaffhausen Power Station

In 1866, Schaffhausen, whose population then hardly exceeded 15,000, could boast of the largest water-power station in Switzerland, housing three 300-h.p. turbines. The turbines transmitted their energy to the workshops along the left bank of the Rhine by means of a system involving massive piers erected close to the bank of the river, which carried mitre gears, differentials, and large rope-pulleys in pairs. Twenty years later, a second installation, the so-called B-station, came into being, also on the left bank, but it was only towards the end of the century that the rope drive was abandoned. The next stage, after another 20 years' interval, was station C, on the right bank, which was a pumped-storage plant with two generating-pumping sets, and was one of the first schemes utilising surplus night and week-end production to meet peak requirements on working days. The new scheme, promoted by the Schaffhausen Corporation and the Nordostschweizerische Kraftwerke AG, and approved on June 24, 1960, by the Federal Council, has the following characteristics: A low-deck-type dam is to be built on the left bank on the extended axis of station C, and will consist of a three-gate spillweir and a power station equipped with two Kaplan turbines operating from a net head of 6·75 m. The generating sets will be sunk into the floor of the building, and the openings provided in the roof of the machine hall for erection and repairs, as well as above the erection bay adjacent to the hall, will be closed by steel covers. These three pits will lie inside the track of the travelling gantry, which will handle the heaviest parts of the generating equipment, the turbine stoplogs, and the emergency gates of the regulating weir. The gantry rails will be 3·60 m above the head-race level and will form part of the upper horizontal plane of the power and spillweir blocks; there will be no other superstructure, so that the harmony of the landscape will not be affected in any way. The scheme is designed for a net discharge capacity of 425 m^3/sec and an output of 22 MW, and will produce, on completion of the storage facilities planned in the catchment area of the Rhine, a mean annual output of 160 million kWh, of which 52% will be during the six months of the summer period. The first generating set is expected to undergo its trial runs in August 1963, in order to be on line in the autumn of the same year. (A. Zeindler, *Technica*, Vol. X, No. 10, May 12, 1961, pp. 635–636, 3 ff.)

Concrete-Faced Rockfill Dam

The structure described is the Borumba irrigation dam on Yabba Creek, near Gympie, South-east Queensland, tenders for which were to be invited last January. The dam will be 145 ft in maximum height above the foundation by 930 ft in crest length, and will involve the placing of 450,000 cu yards of rockfill and 24,000 cu yards of concrete. The rockfill embankment is to be constructed by dumping in lifts, provision being made for sluicing of the material with water as it is being dumped. One of the characteristics of the structure is an upstream zone of placed rockfill with a facing consisting of reinforced-concrete slabs about 1 ft thick and approximately 30 ft square. (*Australian Civil Engineering and Construction*, Vol. 2, No. 5, February 3, 1961, pp. 43/44, 2 ff.)

Keepit Dam Power Plant. In the abstract published in our June issue on the completion of Keepit dam it was stated that no power facilities were included. Although this dam was built for purposes of water regulation, water supply and irrigation, it contains a 6,000-kW hydro-electric set which was supplied by The Harland Engineering Co. Ltd., Alloa, and has been running since the beginning of the year. It comprises an 8,500 h.p. vertical Francis turbine running at 250 r.p.m. under a gross head of 130 ft, and driving an 11-kV 7,500-kVA umbrella-type alternator. The spiral casing and draft tube were manufactured in Australia by Harland Engineering (Australia) Pty. Ltd., and the remainder of the turbine parts, the alternator and exciter were manufactured in Scotland.

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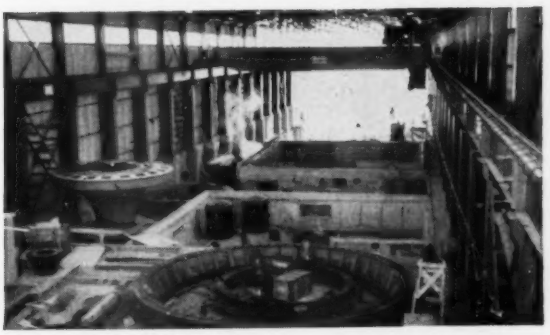

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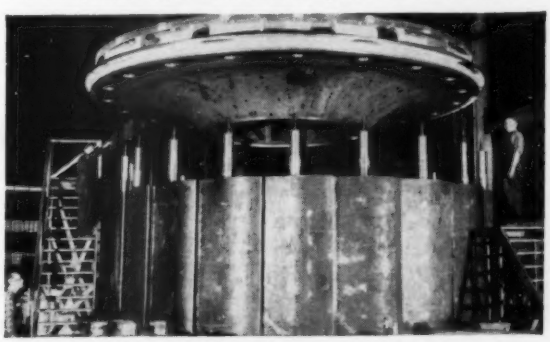

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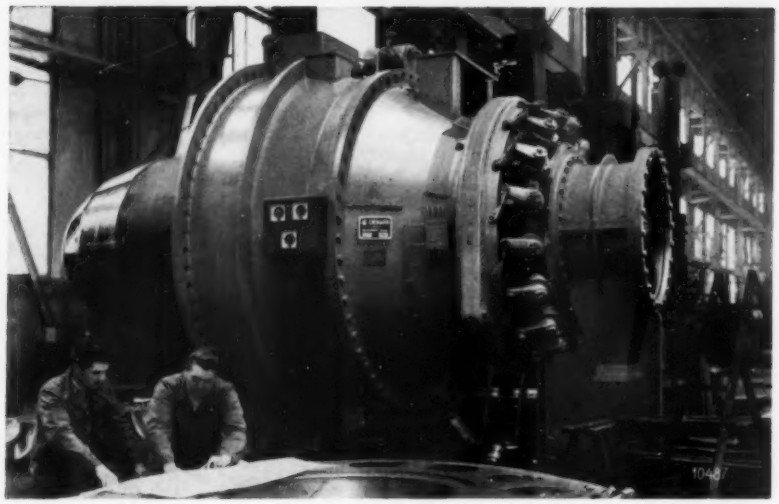

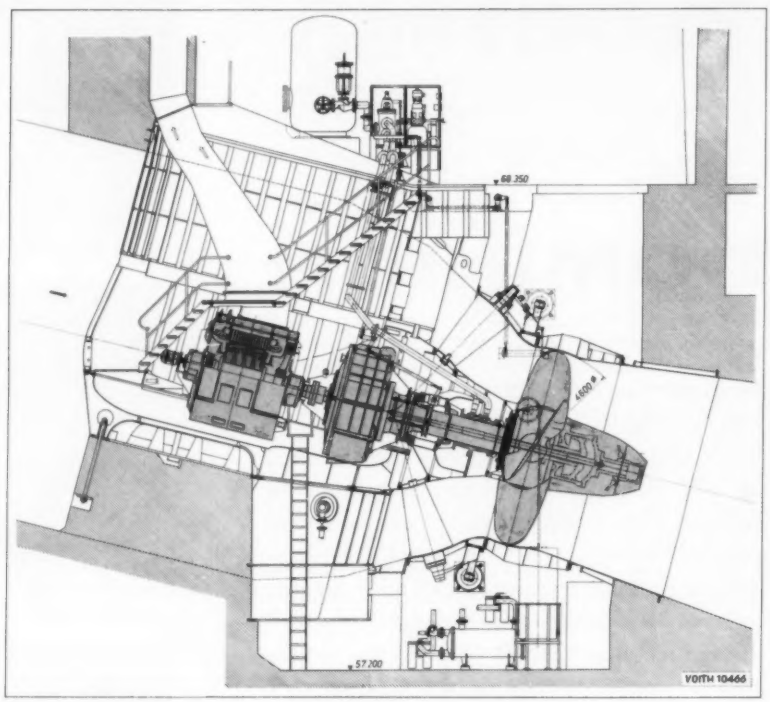

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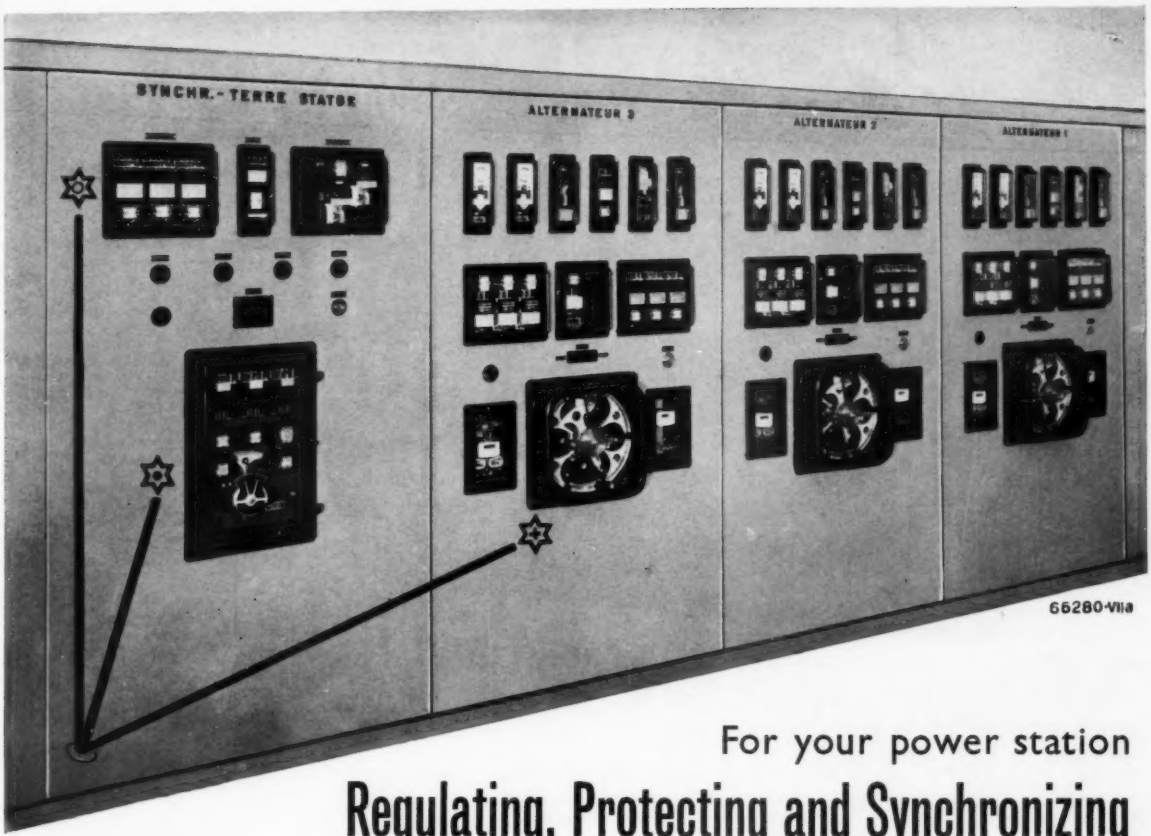

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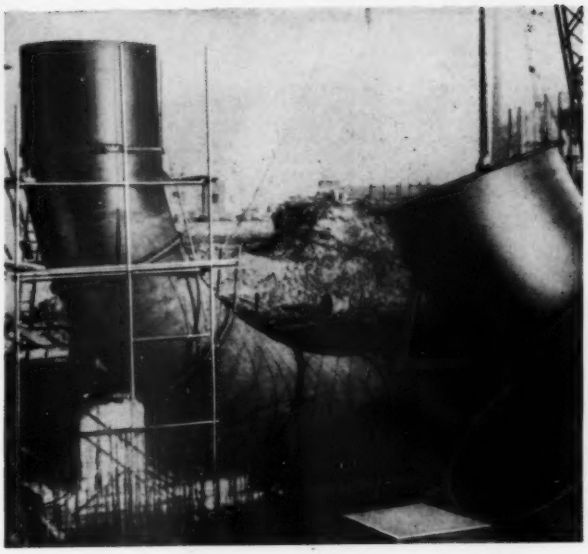

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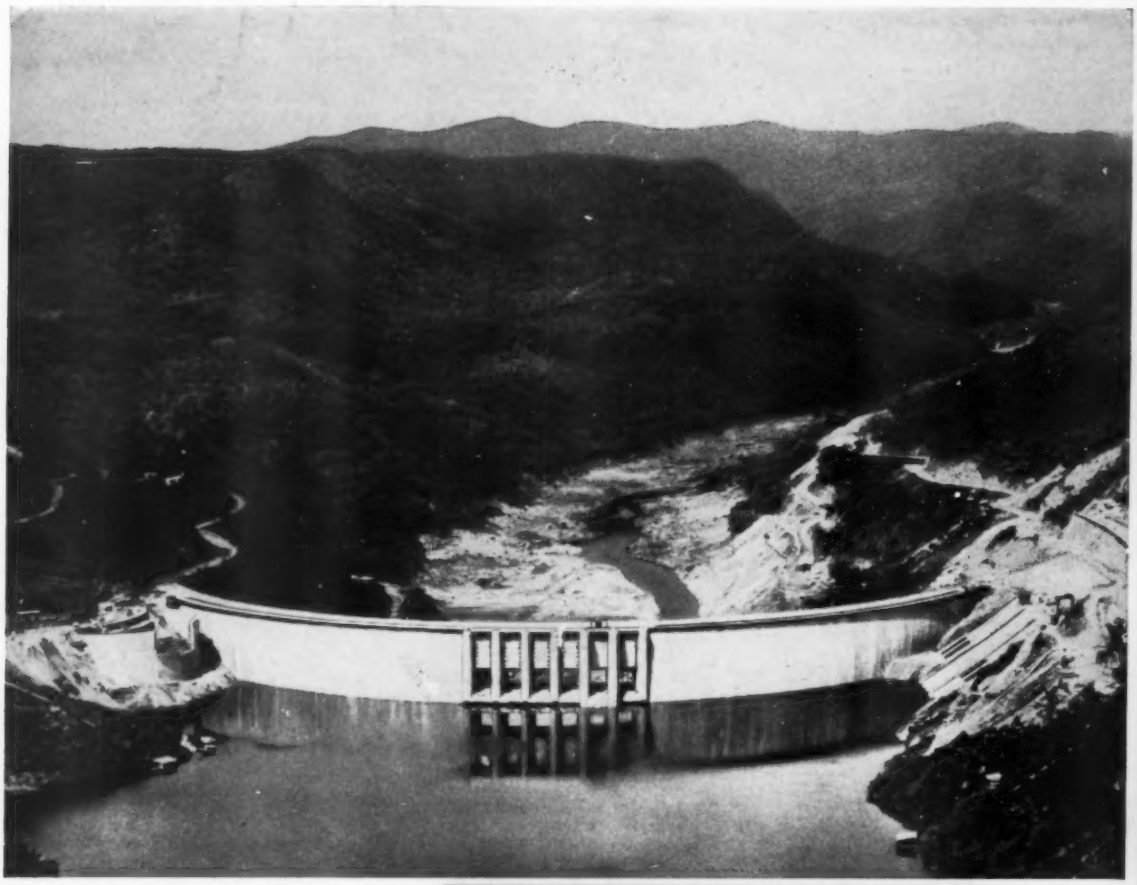

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